Water-Supply and Irrigation Paper No. 111 Series O, Underground Waters, 29

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, Director

PRELIMINARY REPORT

ON THE

UNDERGROUND WATERS OF WASHINGTON

BY

HENRY LANDES

WASHINGTON
GOVERNMENT PRINTING OFFICE.
1905

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of the United States, folios and separate sheets thereof; (8) Geologic Atlas of the United States, folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports.

The following Water-Supply Papers are out of stock, and can no longer be supplied: Nos. 1–16, 19, 20, 22, 29–34, 36, 39, 40, 43, 46, 57–65, 75. Complete lists of papers relating to water supply and allied subjects follow. (PP=Professional Paper, B=Bulletin; WS=Water-Supply Paper.)

Series I—Irrigation.

WS 2. Irrigation near Phœnix, Ariz., by A. P. Davis. 1897. 98 pp., 31 pls. and maps.
WS 5. Irrigation practice on the Great Plains, by E. B. Cowgill. 1897. 39 pp., 11 pls.
WS 9. Irrigation near Greeley, Colo., by David Boyd. 1897. 90 pp., 21 pls.
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WS 32. Water resources of Porto Rico, by H. M. Wilson. 1899. 48 pp., 17 pls. and maps.
WS 43. Conveyance of water in irrigation canals, flumes, and pipes, by Samuel Fortier. 1901. 86 pp., 15 pls.
WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.
WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.
WS 87. Irrigation in India (second edition), by H. M. Wilson. 1903. 238 pp., 27 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Pt. II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Pt. III.

Series J—Water Storage.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by J. B. Lippincott. 1902. 100 pp., 32 pls.
WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.
WS 86. Storage reservoirs on Stony Creek, California, by Burt Cole. 1903. 62 pp., 16 pls.
WS 89. Water resources of Salinas Valley, California, by Homer Hamlin. 1904. 91 pp., 12 pls.
WS 93. Proceedings of first conference of engineers of the reclamation service, with accompanying papers, compiled by F. H. Newell, chief engineer. 1904. 361 pp.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Pt. IV.

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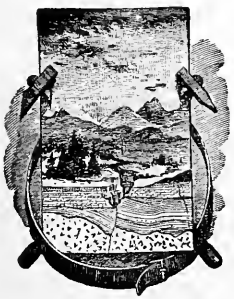

WASHINGTON

GOVERNMENT PRINTING OFFICE

1905

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., May 4, 1904.

SIR: I have the honor to transmit herewith, for publication in the series of Water-Supply and Irrigation Papers, a preliminary report descriptive of the underground waters in the State of Washington, prepared by Mr. Henry Landes under the direction of Mr. N. H. Darton, geologist in charge of the western section of hydrology.

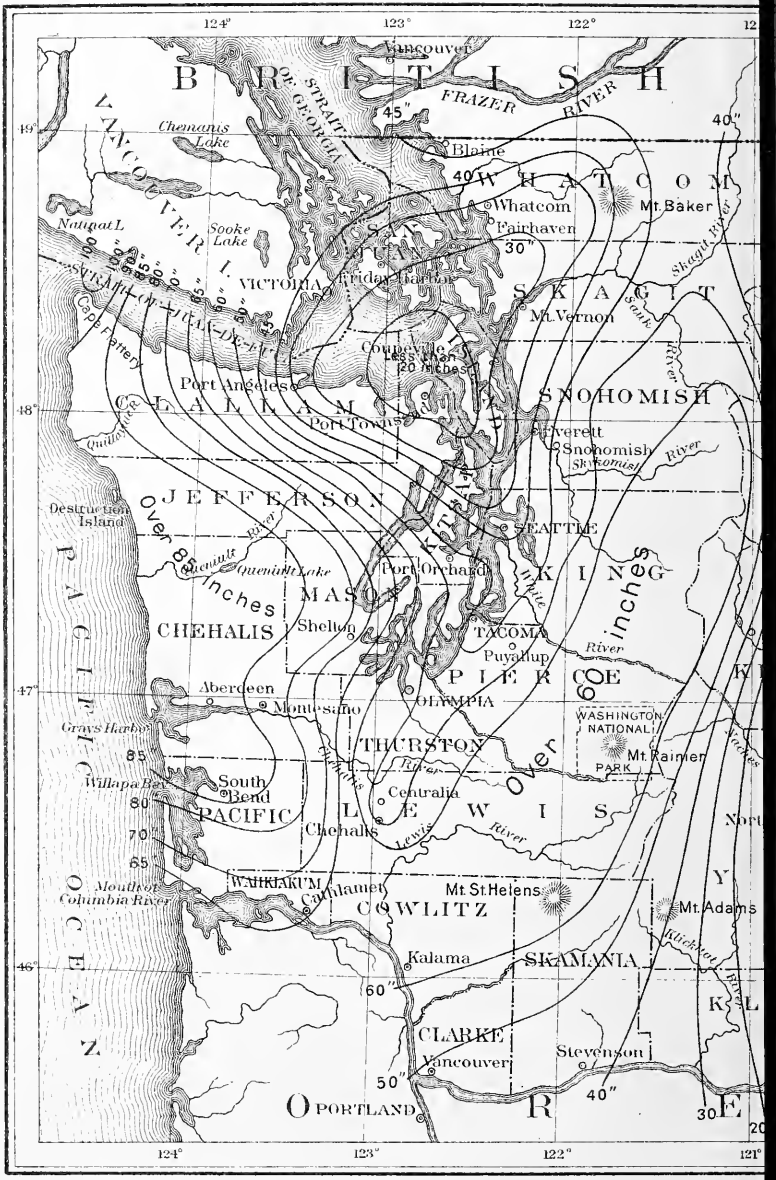
It is believed that the report is a valuable contribution to the knowledge of the water resources of the State.

Very respectfully,

F. H. NEWELL,
Hydrographer in charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

U. S. GEOLOGICAL SURVEY



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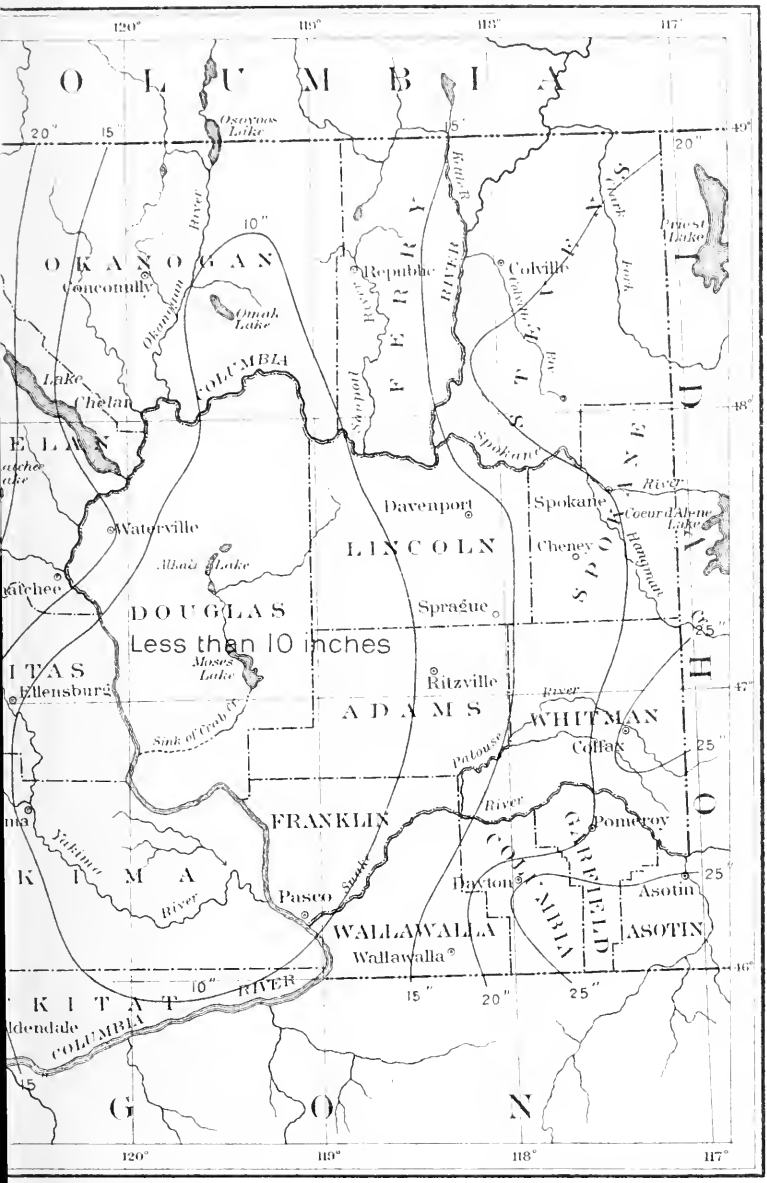

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(Corrected to December, 1898.)

PRELIMINARY REPORT ON THE UNDERGROUND WATERS OF WASHINGTON.

By Henry Landes.

INTRODUCTION.

This report contains a brief account of the water resources of Washington as represented by municipal supplies, deep wells, and springs. For each county a general statement is made, giving the location, rainfall, and most striking features of topography and geology. Following this are detailed statements which give data concerning the municipal systems, deep wells, and springs, and which have been secured entirely by correspondence. The blanks sent to the clerks or other officials of the cities and towns regarding municipal water supplies were practically all filled out and returned, so that this information is complete to the present time. The blanks for the deep wells were not returned as generally as was desired, but almost every section of the State where such wells occur is represented, and those described may be taken as types of their kind in each county. Springs occur so very generally throughout the State that only a small fraction of them may be said to be represented in the blanks filled out and returned, but, as in the case of the wells, those mentioned are typical of their class, and it is only necessary to recall that the number given in every county may be multiplied many times. Every effort has been made to eliminate inaccuracies.

No general statements are made concerning the rainfall, topography, and geology of the State as a whole, since these are given for each county. A rainfall map is included in order to show at a glance what the precipitation is in any section, also the contrasts between one part of the State and another.

ADAMS COUNTY.

General statement.—Adams County lies south and east of the central part of the State, on the line of the Northern Pacific Railway, between Columbia River and Spokane. The topography is that of a gently sloping plain, descending from a height of 1,900 feet in the

northeast corner to 700 or 800 feet in the southwestern part as Columbia River is approached. The plain-like character of the surface is modified by occasional valleys locally known as "coulees." The drainage is to the south and the southwest, toward Snake and Columbia rivers. Cow Creek is the principal stream; the other streams as a rule are intermittent and are active only in the late winter and spring months.

This county lies within the dry region of central Washington, where the precipitation is light and is confined to the winter and spring months. In the western half of the county the average yearly rainfall is 10 inches or a little less, while in the eastern half it is from 10 to 15 inches. There is a regular increase in the amount of rainfall with the increase in elevation, and hence the precipitation is greater in the northeastern part of the county than in the southwestern portion, and there is more rain in uplands than in the valleys.

The Columbia River lava, or basalt, is the principal rock in Adams County. It forms the bed rock everywhere except in the southwest corner, where the Ellensburg beds, composed of sands and clays, appear. As a rule the rocks are covered with a thick coating of soil, the exceptions being the valley sides and occasionally the valley bottoms. The soil is fine grained, of good quality, and very productive when supplied with the proper amount of moisture. Grazing and wheat raising are carried on very successfully in nearly all parts of the county.

Despite the small rainfall, there is little or no difficulty in securing a good supply of water for domestic purposes. At depths of from 300 to 500 feet wells yield large quantities of good water. The water-bearing strata are usually layers of very porous or cellular basalt. Wherever such layers outcrop along the border of a valley, springs are commonly found.

Municipal systems.—Ritzville is the only town in the county reported as having a water-supply system. The water is obtained from a well having a depth of 385 feet. In this way a supply of good water is secured. The water level in the well does not vary during the day or year and is not affected by pumping. The water is pumped into reservoirs and is distributed by gravity throughout the town. Besides serving as a domestic supply, the water is used in irrigating the lawns and gardens.

Deep wells.—Besides the well which supplies Ritzville, another deep well has been drilled at the same place by the Northern Pacific Railway Company. This well has a diameter of 8 inches and a depth of 355 feet. The water column stands at a height of about 240 feet. There is no variation in the water level during the day or year, and it is affected slightly by pumping. It is used by the railway to obtain water for locomotives.

At Cunningham a well has been drilled by Thomas and James O'Hair. This well has a diameter of 6 inches and a depth of 426 feet. The water column stands at a height of 356 feet and remains stationary throughout the year. This well was drilled at a cost of $1,066. A wind pump was erected at a cost of $290. The above wells serve as a type for those of Adams County.

Springs.—As a type of the springs found in Adams County, the one owned by G. W. Bassett, near Washtucna, may be noted. The water issues as a stream from the honeycombed or porous basalt, and varies but little in quantity during the year. It is sufficient to supply the town of Washtucna, and some of it is used for irrigating purposes as well. The water is soft, carries no sediment, and has no unpleasant taste.

Along Cow Creek, a tributary of Palouse River, in the eastern part of the county, there are a number of good springs.

ASOTIN COUNTY.

General statement.—Asotin County lies in the extreme southeast corner of the State. It is in the main a plateau region, deeply dissected by canyons. The higher parts of the plateau have an elevation of about 5,000 feet above sea. The canyon of the Snake, along the eastern and a part of the northern boundaries of the county, has a depth of 3,000 to 4,000 feet. Leading into the larger canyon from the southwest are the smaller canyons of Grande Ronde River and Asotin Creek.

The average rainfall is 25 inches and is sufficient to afford an ample water supply. On the higher parts of the plateau the precipitation is sufficient to produce a forest growth of firs, pines, and other coniferous trees. On the lower parts of the plateau bunch grass grows luxuriantly and it is only in the deep valleys that irrigation is necessary.

The bed rock is basalt, except in occasional instances where the streams have cut through the lava and exposed the underlying granites and other crystalline rocks. The soil is very thick and, since it is of basaltic origin, is of good quality.

Only in the valleys has the county been settled to any degree. In the deeper valleys, as that of the Snake, irrigation is necessary in order to produce fruit, vegetables, and other products, but for this purpose there is an ample supply of water at hand. Water from Asotin Creek is used to irrigate a large area of flat land at Clarkston, and a sagebrush plain has been converted into an oasis of alfalfa meadows, fruit orchards, and vegetable gardens. In the gravels and sands of the valleys good water may be had from wells that vary in depth from 20 to 50 feet.

Municipal systems.—Asotin, the county seat, is situated on Snake River at the mouth of Asotin Creek. The water supply of the town

comes primarily from Asotin Creek, but some dependence is placed on wells and cisterns. The creek rises in the Blue Mountains and carries pure, clear water without any contamination. Besides serving as a domestic supply the water is used for the irrigation of lawns and gardens. The supply is sufficient for the present and in all probability for all future needs.

Clarkston, on Snake River opposite Lewiston, also gets its supply of water from Asotin Creek. The water is carried by a flume 16 miles in length to a point on the hillside immediately above the town and from there is distributed by pipe lines. At present this forms the sole supply for the town, but a deep well is being bored as a possible additional source of supply. An analysis of the water of Asotin Creek made by Professor Fulmer at Pullman on January 29, 1903, showed 6.18 grains of solid matter in each gallon of water. The solid matter was found to be wholly free from objectionable qualities.

Along Snake River, especially in the vicinity of Asotin, are a number of wells which range in depth from 20 to 35 feet. The water is obtained from gravel and sand and is of good quality. This water supply is intimately connected with the river, as the water in the wells and in the river is always at the same level.

CHEHALIS COUNTY.

General statement.—Chehalis County lies on the western border of the State, fronting the Pacific Ocean. The coast line here is irregular, the most marked indentation being Grays Harbor. From the narrow belt of sand dunes along the coast the surface rises by irregular hills until the low mountains of the Coast Range are encountered on the eastern border of the county. Chehalis and Queniult rivers flow in broad valleys from east to west across the county. The region between these streams is drained by Humptulips River, which flows southwest and empties into Grays Harbor.

Along the coast the yearly rainfall averages about 90 inches, but inland it decreases gradually, dropping to 65 inches at the extreme eastern edge of the county. Practically the whole county is covered with a luxuriant growth of vegetation, the only exceptions being the small areas of outwash glacial gravels, commonly known as "prairies," where but few trees have yet begun to grow.

The rocks of Chehalis County as far as known are of Tertiary age. Marine Eocene fossils have been identified at Porter and Elma, in the eastern part of the county, and marine Pliocene fossils have been found at Granville, at the mouth of Queniult River. The Tertiary rocks are chiefly clastic, consisting of beds of clay, sand, and gravel. Occasionally they contain a small igneous dike, usually of basalt. Nearly all of the county north of Grays Harbor and Chehalis River

has been glaciated, and the glacial till, with layers of sand and gravel, is very thick.

The very heavy rainfall yields an abundant supply of water for every purpose. The lakes and the deep porous soil are great storage reservoirs, which feed the streams at all seasons and give them an even flow. The only contamination is due to the decay of vegetal matter in the streams and lakes. In the glacial sediments and in the gravels and sands of the river valleys excellent water may be had from wells of moderate depth. It is not likely that deep wells will ever be necessary in order to afford a supply of water in any part of the county. Since the sedimentary rocks above mentioned are known to be folded, it is possible that artesian basins have been formed, within which flowing wells may be secured by drilling.

Municipal systems.—Aberdeen, at the head of Grays Harbor, gets its supply of water from a creek. The quantity obtained in this way is hardly sufficient for present needs, and water from another creek near by will soon be used. The system of waterworks used is that of direct pressure. As a rule the wells do not yield good water, since in digging them marine deposits of mud and sand are penetrated.

A sanitary analysis of the Aberdeen city water was made April 14, 1901, by Prof. H. G. Byers, of the University of Washington, with the following result:

Analysis of water from city well at Aberdeen.

[Parts per million.]

Total solids	75.69
Volatile solids	12.50
Nonvolatile solids	63.19
Nitrogen as nitrites	None.
Nitrogen as nitrates	.090
Nitrogen as free ammonia	None.
Nitrogen as albuminoid ammonia	.021
Oxygen consumed	.966
Chlorine	6.50

The water supply of Cosmopolis is obtained chiefly from wells, but in part from some creeks owned by the Grays Harbor Commercial Company. From the creeks to the town a gravity system of waterworks has been installed. The water is soft, of good quality, and is ample for present needs and probably for all future demands.

Hoquiam, on Grays Harbor, secures its water supply from the headwaters of Little Hoquiam River, which affords a supply of good water sufficient for present and future needs. The water is pumped into a reservoir and then distributed by gravity. Besides serving the domestic demands the water is also used as a boiler supply. Practically no wells are used in the city, especially in that part which is situated on the tide flats.

Montesano, the county seat of Chehalis County, obtains its water supply from some springs north of the city. The supply is suffi-

cient for the present, but some other source may be necessary in the future. From the springs the water flows into a reservoir and is then distributed by gravity. The water is of good quality and there are no sources of contamination. In Montesano a few wells have been dug, usually about 35 feet in depth. The water-bearing stratum is gravel. The water from the wells is good and may be obtained in large quantities. The water level varies only in the dry summer months, when it falls somewhat.

Ocosta, a town of about 300 inhabitants, on the southwest shore of Grays Harbor, obtains a town supply from wells and springs. The water is of good quality and ample for present needs. The wells have an average depth of 50 feet and the water is obtained from beds of sand. The sand is overlain by clay, so that there is no contamination from the surface. The water level in the wells is somewhat lower in summer than in winter.

CHELAN COUNTY.

General statement.—Chelan County lies a little north of the center of the State, and extends from the summit of the Cascade Mountains southeast to Columbia River. The topography is very rugged, since it includes some of the most broken parts of the Cascades. From the northwestern border of the county, which has an altitude of 7,000 to 8,000 feet, the surface slopes southeastward to the Columbia, where the elevation is only about 700 feet above the sea. The streams flow in deep valleys or canyons, and the divides are very sharp and lined with rows of peaks. There are three prominent drainage systems, all having northwest-southeast courses. Beginning at the north these are Stehekin River and Lake Chelan, Entiat River, and Wenatchee River.

The rocks of Chelan County are mainly granites, gneisses, schists, and other crystallines. The principal exception is the sandstone of Eocene age in the southern part of the county. The sandstone is of lacustrine origin and forms a belt reaching from Wenatchee to Leavenworth in an east-west course and from the southern border of the county northward for about 30 miles.

The rainfall is greatest along the extreme western border, or in the region of the highest mountains, where it is from 40 to 60 inches a year. In the descent eastward it decreases rapidly until in the valley of the Columbia it averages but 15 inches yearly. In the mountains much of the precipitation is in the form of snow, and along the summit of the Cascades are many glaciers. The snow-fed mountain streams carry an abundance of the purest water, and in all parts of the county is an excellent water supply. On the alluvial fans and terraces along Columbia and Wenatchee rivers large tracts are now under successful irrigation, the water being supplied by the mountain streams.

Municipal systems.—The town of Chelan has obtained its water in part from springs and in part from Lake Chelan. A system of waterworks is now being installed whereby the water from the lake will be pumped into reservoirs and then be distributed throughout the town by gravity. As the water of the lake comes from the snow fields and streams of the high mountains, and is not contaminated, it is exceedingly pure and healthful. Besides serving as a domestic supply, a large amount of water will be used for irrigation within and about the town. Repeated efforts have been made to obtain water from wells, but although depths of 100 feet were reached no successful wells have been dug on the town site.

Lakeside, at the southern end of Lake Chelan and near the town of Chelan, has in the past depended upon wells for its water supply. Like the town of Chelan, it has under construction a system of waterworks which will draw the supply from the lake.

Wenatchee, the county seat of Chelan County, situated on Columbia River at the mouth of the Wenatchee, obtains its supply of water from a creek which flows out from the Cascade Mountains. This supply is sufficient for present needs, but must be supplemented by something better in the future. Besides its use as a house supply, the water is extensively used for irrigating lawns, gardens, and orchards. There are no successful wells in the region about Wenatchee.

Springs.—In the eastern part of the county a number of springs are employed for domestic supply and for irrigation. The spring owned by George Brisson, which may be regarded as a typical one, issues as a stream from a porous basaltic rock. The water is of good quality, carries no sediment, remains constant for the most part, but decreases somewhat in flow in the autumn.

CLALLAM COUNTY.

General statement.—Clallam County lies in the extreme northwest corner of the State, and has a frontage on both the Pacific Ocean and the Strait of Juan de Fuca. It includes the northern half of the Olympic Mountains, the highest peak of which, Mount Olympus, stands on the southern border of the county. The Olympics are rugged, deeply dissected mountains, and reach outward almost to the coast, leaving a narrow belt of hills immediately along the shore. This belt is much wider along the Pacific coast than along the strait. The highest mountain peaks are from 6,000 to 8,000 feet above the sea.

The greatest rainfall in the State is at Cape Flattery, where the average for the year reaches 100 inches. From this point eastward the precipitation decreases regularly, until at the eastern border of the county it is from 20 to 30 inches per year. In the highest mountains

much of the precipitation is in the form of snow, and the snow fields and glaciers serve as reservoirs from which the streams are fed during the summer months. The great abundance of pure mountain water will not only serve as an ample supply for all municipal and domestic requirements, but will afford excellent water power. All parts of the county except the highest mountains are densely forest clad, and the forests are eminently helpful in retarding the run-off and equalizing the flow of the streams from season to season.

In a belt varying from 10 to 20 miles in width, extending along both the north and west coasts, the rocks are of Tertiary age and represent marine sediments. Eocene or Oligocene fossils have been identified along the Strait of Juan de Fuca between Twin River and Gettysburg, and fossils that are probably of upper Miocene age have been found near the mouth of the Quillayute River on the west coast. The Tertiary rocks are all sedimentary, consisting chiefly of conglomerates, sandstones, and shales. Within these rocks a good supply of water may be had from comparatively shallow wells.

To the south and east of the belt of rocks above mentioned, within the higher Olympics, the rocks consist of schists, slates, and other metamorphics, with great intrusions and extrusions of igneous rocks. The age of these rocks and their relations to the sedimentaries above described have never been determined. Along the northern border of the county the glacial sediments are commonly very heavy, and from these it is usually easy to secure good water by means of wells from 20 to 40 feet in depth. There are many large lakes within the county, such as Ozette and Crescent, which are reservoirs of the purest water. Lake Crescent is a very deep lake, at the border line of the high mountains, with water of extraordinary blueness and purity.

Municipal systems.—The water supply of Port Angeles, the county seat of Clallam County, comes in part from wells, but in the main is derived from Frazer Creek, which is a small stream rising in the Olympic foothills back of the town and flowing through the town site. About one-half of the water of the stream is taken out in pipes and distributed by gravity. As the water is often subject to contamination, and is of insufficient quantity for the future, it affords a somewhat unsatisfactory supply. A plan is on foot to secure water from Little River, which is within 6 miles of the city. This stream rises in the snow fields of the Olympic Mountains and carries a large volume of excellent water. The wells that have been dug about Port Angeles vary in depth from 12 to 40 feet. The water-bearing strata of sand and gravel are overlain by clay, which prevents contamination from the surface. The water level is lowered somewhat in the summer months, but for domestic uses the wells are never exhausted.

Port Crescent, located on the Strait of Juan de Fuca, a few miles west of Port Angeles, secures its water supply mainly from wells, but

to a limited extent from a small lake. The wells range in depth from 16 to 20 feet. Water is obtained from sandstone, which is overlain by a thin layer of soil. The water rises in the wells to within a few few feet of the surface, and the level is scarcely affected by pumping.

CLARKE COUNTY.

General statement.—Clarke County is situated on the southwestern border line of the State, having Columbia River on its southern and western sides, Cowlitz County on the north, and Skamania County on the east. From a low plain along the Columbia the surface rises gradually to the foothills of the Cascades until the northeastern part of the county is reached, which presents a very broken appearance. The principal streams are the North and South forks of Lewis River, Salmon River, and Washougal River.

The yearly rainfall of Clarke County varies in passing from west to east, but it may be said to average about 50 inches. The precipitation is nearly all in the form of rain, the elevation above sea not being sufficient to produce snow to any marked degree.

The bed rock is mainly basalt, except in the northeastern portion of the county, where the metamorphic and granitic rocks of the Cascades prevail. The weathered basalt affords an excellent soil, and agriculture has come to be a very important industry. The soil has formed to such a depth that it contains a good water supply, and surface wells are therefore in common use. Along Columbia River are broad gravel terraces from which large quantities of water are obtained by means of springs and wells. The springs are common along the terrace bases and often yield large amounts of water. The wells are from 25 to 75 feet in depth, and the water-bearing strata are usually overlain by clay, so that surface contamination is at a minimum.

Municipal systems.—Vancouver, the county seat, secures its water supply from 3 springs and 2 wells. The amount thus obtained is sufficient for present needs, and doubtless will be ample for some time to come. There are no sources of contamination, and the water is of excellent quality. A gravity system of waterworks is used. The wells about Vancouver range in depth from 30 to 75 feet. The water is found in a stratum of coarse gravel, which is overlain by clay. It rises to within 25 feet of the surface, and very little change in the level is noted from season to season. The water level is affected only to a slight degree by pumping. Besides its use for domestic purposes, the water system is drawn upon for fire protection, boiler supply, etc. An analysis of the water showed the total solids per gallon of water to be 10.05; organic matter per gallon, 0.60; hardness, 11.30.

Springs.—Five miles east of Vancouver are 3 springs owned by the Vancouver Waterworks Company. The water flows out in streams

from a bed of gravel which outcrops upon a hillside. The flow varies slightly at different times, but is about 1,750,000 gallons daily. The water is soft, has a pleasant taste, and carries no sediment.

COLUMBIA COUNTY.

General statement.—Columbia County lies between Wallawalla County, on the west, and Garfield County, on the east, and reaches from the Oregon line northward to Snake River. The southern part of the county lies within the broad plateau of the Blue Mountains, and has a height of from 4,000 to 5,000 feet above the sea. The northern part is a region of high, rolling hills and deep ravines. Along the northern border Snake River flows in a canyon that has a depth of 1,000 to 1,500 feet.

The rainfall varies from 15 inches a year along Snake River to 25 inches in the central and southern parts. In the Blue Mountains it is sufficient to produce a forest covering. In the northern part of the county the bunch grass which once grew so luxuriantly is fast giving way to wheat fields. In agriculture irrigation is necessary only along the benches or terraces of the Snake, where there are many fine fruit and alfalfa ranches.

As far as known, there are no other rocks in the county save basalt. Some parts of the basalt are very vesicular or porous, and are commonly water bearing. In digging wells an ample supply of good water is generally found within 50 feet of the surface. On the hillsides, wherever the porous basalt outcrops, springs may occur, and they are in common use as domestic water supplies.

Municipal systems.—Dayton, the principal town and the county seat of Columbia County, obtains its water supply from springs. These afford a supply which will doubtless be ample for all time to come. A gravity system of waterworks is used. In a few instances water is obtained from private wells, which range in depth from 25 to 50 feet. The water is found in very porous layers of basalt. In the wells the water level varies slightly with the seasons, but is not affected to any appreciable extent by pumping.

Springs.—Near Dayton are the springs from which the city water supply is derived. The water seeps out from beds of gravel at the base of a hill. The amount of water varies considerably with the season, the flow being reduced in the dry summer months. The water is soft, and no deposits of mineral matter or sediments are found about the springs.

COWLITZ COUNTY.

General statement.—Cowlitz County is situated on the southwestern boundary of the State, north of Clarke County and Columbia River.

The western half of the county is composed of low irregular hills and broad stream valleys; the eastern half is very rough and broken, since it contains the foothills and outlying spurs of the Cascades. The principal streams are Cowlitz, Toutle, and Kalama rivers.

The annual rainfall varies from 65 inches on the western margin to 60 inches in the eastern part. Every part of the county is therefore well watered and heavily forested. There is sufficient water in the streams to supply any possible municipal demands. On the terraces or benches of the larger streams good water is secured from wells at depths between 15 and 50 feet.

In the northern and western parts of the county the prevailing rocks are shales and sandstones of Eocene age. Along Cowlitz River these rocks are coal bearing, and in the neighborhood of Castle Rock and Kelso coal mines have been in operation for some time. The soft coal measures have readily decomposed at the surface, and upon them is a residual soil many feet in thickness. From the soil or the porous rock below water in large quantities is readily obtained by wells of moderate depth. In the southeastern part of the county, in the vicinity of Kalama, the usual rock is basalt, and from it water is secured in wells averaging 25 feet in depth.

Municipal systems.—Castle Rock obtains its water supply from a stream which rises in the foothills east of the town. This supply is sufficient for the present, but must be supplemented in the future by water from some other source. The water is brought from the stream in pipes and distributed by a gravity system. The wells in the vicinity of Castle Rock vary in depth from 15 to 20 feet. The water-bearing material is gravel. The height of the water column depends upon the stage of water in Cowlitz River near by, rising and falling with the river level.

Kalama obtains its water by a gravity system from two creeks. The supply will doubtless have to be increased in the future. The water is very good, the only contamination being from a small amount of decaying vegetation. A few wells are used about Kalama, having an average depth of 25 feet. They are sunk in basalt and, as contamination may be entirely prevented, the water is very good.

DOUGLAS COUNTY.

General statement.—Douglas County is situated immediately east of the central part of the State, within what is commonly known as the "Big Bend" of the Columbia. Its surface is that of a plateau, broken by the Badger Mountains in the western part and by the Saddle Mountains in the southern part, and sloping gently from north to south. Along its northern margin the plateau has an elevation of about 3,000 feet above sea level, which decreases to less than 1,000

feet along the southern border of the county. Within the plateau are three notable canyons or deep clefts, namely, the present valley of the Columbia, and Moses and Grand coulees, the latter doubtless representing a former course of Columbia River. Several small creeks which enter Moses Coulee sink in the sand and do not form a main stream. In Grand Coulee is a chain of lakes, the largest being Blue and Moses lakes. Some of the lakes are fresh, but the majority are alkaline.

Douglas County lies within the region of lowest rainfall in the State. In the northwestern part the average precipitation for the year is 15 inches; in the remainder of the county it is 10 inches or less. The precipitation is largely in the form of snow, especially where the elevation is greatest. There is no forest growth, and prairie conditions wholly prevail. In the highest portions of the county the bunch grass grows abundantly, and cattle raising is an important industry. Here also wheat may be grown successfully, and it has already come to be an important product. In the southern part of the county, where the rainfall is least, irrigation must be practiced in order to carry on agriculture.

The bed rock is practically all basalt except a narrow fringe of granite which is exposed in the canyon walls of the Columbia, and some granite outcrops in the northern end of Grand Coulee. A small area of early Tertiary sandstone underlies the basalt along Columbia River opposite Wenatchee, and late Tertiary lake beds covering a considerable area of the basalt in the southern part of the county should also be noted. From the basalt a very thick and fine-grained soil has been formed, which retains water to an unusual degree. In this way enough water is held within the soil after the winter precipitation to grow and mature the wheat during the coming spring and summer. Within the soil or the porous portions of the basalt below it is usually not difficult to secure a sufficient supply of water for house and farm purposes. Springs are more or less common throughout the county, more particularly at the bases of the cliffs along the Columbia and the coulees. Springs are largely the sources of the lakes mentioned above.

Municipal systems.—The town of Wilsoncreek depends in the main upon wells for its supply of water, but a small stream is also used to some extent. The supply is barely sufficient for present needs, and another source must be sought in the future. While some of the wells have soft water, the others are slightly alkaline. They range in depth from 12 to 54 feet. The more shallow wells obtain water from beds of gravel, while the deeper wells enter the bed rock. The water level in the wells scarcely varies from season to season and is not ordinarily affected by pumping.

Grand Coulee, which has a northeast-southwest direction across the county, was in a former time occupied by Columbia River. Along the course of the coulee there is now a chain of shallow lakes, some of which are fresh, but the most of them are alkaline. The following descriptive matter concerning two of them is taken from Vol. I, of the Annual Report, Washington Geological Survey, for 1901.

Moses Lake, which lies about 12 miles southeast of Ephrata, on the Great Northern Railway, is about 18 miles long and a mile wide, and is very shallow. The average depth is approximately 20 feet. It lies in a shallow basin with low banks, so that a rise of but a few feet would inundate a large section of country. The water is unfit for drinking purposes, but is not strongly alkaline and could probably be used in irrigation. The section of country in which these lakes are located is of course very dry, and supports only a scanty vegetation. Where there is water, however, the soil is very fertile. The lake drains a large area through upper Crab Creek. It has no outlet, but across its foot lies a low range of sand hills through which the water seeps into the sources of lower Crab Creek, which occupies the bed of the canyon below. Along this canyon lie numerous shallow ponds which dry up in summer. The deposits left by these are not of any considerable value, though they contain an appreciable quantity of borax.

An interesting feature of Moses Lake is the fact that it is gradually rising, having risen about 10 feet in the last seven years. If it continues to rise through a few more feet it will break through a clear course into lower Crab Creek and empty into the Columbia.

The analysis of the water of Moses Lake is as follows. The analysis is by H. G. Knight:

[Parts per thousand.]

Total solids	0.32357
Volatile solids	.10095
Nonvolatile solids	.22262
Silica	.01502
Alumina and iron oxide	.00331
Calcium carbonate	.06235
Magnesium carbonate	.07525
Sodium sulphate	.01258
Sodium chloride	.01895
Sodium carbonate	.10914

More interesting is the so-called Soap Lake, or Sanitarium Lake, situated about 6 miles north of Ephrata. This lake is so called because it is so strongly alkaline as to be soapy to the touch, and when a strong wind blows across it the water along the shore is beaten into great rolls of foam. Fish can not live in the water, nor is there any vegetation in this as in Moses Lake. The water is used for bathing, but to those not accustomed to its use the water has a slightly caustic or irritating effect. It is also claimed that it is useful medicinally. There is much of peculiar interest about the lake. It is about 2¼ by three-fourths miles in extent and is very deep in places and probably averages about 40 feet. It drains only a very small area of country and has neither inlet nor outlet in the form of streams. It is located in a deep basin walled to the height of 100 feet or more on the east and west by cliffs of black basalt. The land to the north and south rises slowly; on the south to nearly the height of the cliffs, but on the north the rise is so slight that should the lake rise 15 feet it would empty into the next of the chain of lakes to the north. The source of the water of the lake is said to be a spring in the center. The Indians of the

neighborhood assert that only a few years since the lake was very small and was fed by this strongly alkaline spring. Fresh water is, however, continually seeping in from the shores, as is shown by the fact that fresh-water wells may be sunk even but a few feet from the shore, and that the cattle, disliking the strongly alkaline water, face the shore to obtain the sweeter seepage.

The analysis of the water is as follows:

[Parts per thousand.]

Total solids	28.2669	Potassium carbonate	.51177
Volatile solids	.62503	Lithium sulphate	Trace.
Nonvolatile solids	27.64186	Phosphorus pentoxide	.12018
Silica	.12816	Carbon dioxide (semicombined)	1.37034
Alumina and iron oxide	Trace.	Borax	None.
Calcium sulphate	Trace.	Iodine	None.
Calcium carbonate	Trace.	Free ammonia	.03400
Magnesium sulphate	.39099	Albuminoid ammonia	1.1060
Sodium sulphate	6.34872	The specific gravity	1.0260
Sodium chloride	5.81384		
Sodium carbonate	14.08901		

FRANKLIN COUNTY.

General statement.—Franklin County lies between Wallawalla County on the south and Adams County on the north, with Columbia River as its western boundary. The surface is that of a plain, sloping gently toward Columbia and Snake rivers. In the northwest corner of the county the plain is about 300 feet above the surface of the Columbia, giving rise to the cliffs along the stream known as the White Bluffs. In the eastern part of the county the plain rises to a height of 300 to 400 feet above the level of the Snake. Near the confluence of the two rivers the plain decreases in elevation and the banks of the streams are but a few feet in height.

The average rainfall is about 10 inches a year. This will not admit of any forest growth and scarcely permits of the growth of bunch grass. Agriculture may be carried on only where irrigation is possible. Irrigated tracts along the rivers yield very fine returns in alfalfa and fruit.

In the western part of Franklin County the outcropping rocks are thin beds of sand and clay, with layers of volcanic dust, which represent Miocene lacustrine sediments. Such deposits at one time may have covered the entire county, but in the eastern portion basalt alone now appears. At a number of places successful wells have been drilled in the basalt, the water being found in the more porous or vesicular parts of the rock. The depth of the wells varies from about 200 to nearly 700 feet. It is evident that, in advance of drilling, the depth at which water will be found is conjectural. In the western part of the county a well is now being drilled in the sedimentary rocks noted above.

Deep wells.—W. T. Braden, living at Connell, completed a deep well in September, 1902. The well is located in a canyon, and its mouth has an elevation above the sea of 840 feet. It has a diameter of 5 inches and a depth of 676 feet. The well is cased from the surface to solid rock, a distance of 100 feet. The water rises in the well about 36 feet and is brought to the surface by a wind pump. The temperature of the water when brought to the well mouth is 51° F. The water level does not vary during the day or year and is not affected by pumping. The cost of the well, including the pumping machinery, was about $3,000.

There are several firms making a business of drilling wells in Franklin County, the most prominent of which is the Reinbolt Well Drilling Company. A few of the wells drilled by this company, with their depths, are here given: H. W. Brummond, 410 feet; John Finkbiner, 485 feet; John L. Wordheim, 212 feet; Connell Land and Improvement Company, 243 feet; William Fisch, 265 feet; William Elgin, 323 feet; Charles Schelley, 487 feet.

Springs.—A number of springs are known to exist in the eastern part of Franklin County, although but a few of these have been reported. These springs are oftentimes the sources of supply for small lakes which have no outlets.

JEFFERSON COUNTY.

General statement.—Jefferson County is situated in the northwestern part of the State, between Clallam County on the north and west and Chehalis and Mason counties on the south, and extends from Puget Sound to the Pacific Ocean. Topographically the surface presents a great diversity. The county contains the most rugged portions of the Olympic Mountains, the only areas that are comparatively level being in the northeastern part, within a few miles of the shores of Puget Sound. This is the only part of the county inhabited to any degree, there being no inhabitants within the Olympics and but very few west of the mountains along the Pacific coast.

The rainfall along the western coast averages over 85 inches a year. It decreases steadily eastward and is less than 20 inches in the vicinity of Port Townsend. The district east of the Olympics has a low rainfall because the high mountains divert to some degree the rain-laden westerly winds. Within the Olympics are several glaciers and snow fields which feed the streams during the rainless months of summer.

The band of Tertiary rocks which encircles the Olympic Mountains outcrops in both the eastern and the western parts of the county. The rock series is composed chiefly of conglomerates, sandstones, and shales, and without doubt contains large quantities of water which

can be secured by means of wells. The bed rock just mentioned is often deeply buried by glacial sediments, which are important reservoirs.

Municipal systems.—Port Townsend obtains its water supply from driven and dug wells owned by the Spring Valley Water Company. From these wells 250,000 gallons per day are obtained by pumping. This supply is hardly sufficient for present needs, and a gravity system from some stream coming out of the Olympic Mountains is in contemplation. The water in use at present is of good quality. The wells do not enter bed rock, the water-bearing materials being sand and gravel. A heavy bed of clay which lies above the sand and gravel prevents contamination. An analysis of the Port Townsend water is given below:

Analysis of water from Port Townsend, Wash.

[Grains per gallon.]

Silica	1.255
Alumina and iron oxide	.146
Calcium carbonate	16.731
Magnesium carbonate	6.987
Magnesium chloride	11.200
Calcium sulphate	1.826
Sodium and potassium chlorides	29.236
Sodium and potassium carbonates	1.531
Total solids	68.912

Port Ludlow obtains its water supply from a small creek. The water is soft, of good quality, and sufficient for all probable future needs. A gravity system of waterworks is used. The water is drawn upon for a boiler supply for the Port Ludlow mills as well as the domestic supply for the town.

KING COUNTY.

General statement.—King County is situated west of the center of the State and extends from the summit of the Cascades westward to Puget Sound. It lies between Snohomish County on the north and Pierce County on the south. Along the shores of the sound the surface is that of a plain, rising to a height of about 300 feet above the sea; east of the plain are hills and ridges, the latter having in general a north-south direction; immediately east of this belt are the mountains, rising from a height of about 3,000 feet along their western border to an average height of 6,000 feet, when the summit line is reached. The mountains are deeply dissected by the several forks of Snoqualmie, Cedar, Green, White, and other rivers.

The annual rainfall varies from 40 inches along the shores of the sound to more than 60 inches within the mountains. About the sound practically all of the precipitation is in the form of rain, but with increase in elevation the snowfall becomes important, and in the higher mountains the amount of snow falling each year is very large.

The presence of snow and glaciers has an important bearing on the run-off of the streams from season to season. Apart from its value as sources of municipal supply, the movement of so much water from higher to lower levels is productive of great power. Already the water power of the cataracts and falls is being harnessed for the use of man. At Snoqualmie Falls, 25 miles east of Seattle, a plant has been installed which develops a total of 10,000 horsepower. Snoqualmie River at this point has a vertical drop of 270 feet, with a flow of about 1,000 second-feet during the driest season and about ten times as much during the periods of high water.

The strata which outcrop about the sound and eastward for a distance of about 25 miles are mainly clastic rocks of early Tertiary age. At many places they are coal bearing, and important coal mines have been developed at Black Diamond, Franklin, Palmer, Renton, Newcastle, Issaquah, and elsewhere. East of the Tertiary sediments are the metamorphic and igneous rocks of the Cascades, which in King County at least are virtually unstudied. In the vicinity of the sound bed rock outcrops but rarely, being covered by a heavy mantle of glacial sediments. At many places this mantle is known to be more than 500 feet in thickness. The glacial sediments comprise beds of till, with stratified sand, gravel, and clay. From the layers of sand and gravel which are interstratified with the till an abundant supply of good water is generally obtained. The wells are usually shallow, it being rarely necessary to go deeper than 40 feet. Springs are very common about the bases of the hills or upon the hillsides where the water-bearing gravels and sands outcrop.

Municipal systems.—The town of Auburn obtains its water supply chiefly from wells, which vary in depth from 40 to 50 feet. The wells are sunk in the alluvium of the White River Valley, the water-bearing materials being sand and gravel. In no instance has bed rock been reached. In some instances shallow wells have been used for a little time, but in these the water is not good. The water from the deeper wells is soft, is not contaminated, and is obtained in ample quantity, in some instances rising to the surface. No other supply of water for drinking purposes is contemplated, but it is likely that water for fire protection will be obtained from White River.

The city of Ballard obtains about 300,000 gallons of water daily from springs and deep wells, about half from each source. The wells are the more satisfactory. While this amount is ample for present needs, it will not be sufficient in the course of time if the city continues its rapid growth. It is very likely that in the near future the supply for Ballard will be secured from the Cedar River system owned by the city of Seattle. The surface wells in Ballard have depths of 12 to 20 feet, but the wells used for the municipal supply average about 160 feet in depth. For the most part they penetrate

glacial till or hardpan, the water-bearing strata being beds of sand and gravel. The system of waterworks is direct pressure.

A sanitary analysis of water from one of the deep wells in Ballard, made by Prof. H. G. Byers, of the University of Washington, is as follows:

Sanitary analysis of water from deep well at Ballard.

[Parts per million.]

Total solids	165.66
Oxygen consumed	2.89
Chlorine	5.50
Nitrogen as free ammonia	.874
Nitrogen as albuminoid ammonia	.100
Nitrogen as nitrites	None.
Nitrogen as nitrates	.320

The municipal supply of water for Columbia City is obtained from Seattle. A few private wells are in use having an average depth of 30 feet. They penetrate glacial deposits only and from them water of good quality is obtained.

Water for the town of Enumclaw is furnished from the system of the White River Lumber Company. The water comes from streams flowing out from the Cascade Mountains, and as there are no sources of contamination it is of excellent quality. A gravity system of waterworks has been installed. It is possible that in the future the town supply may be taken from some springs located about 4 miles away. The springs are at a height of about 270 feet above that of the town. A few wells are in use about Enumclaw, which have an average depth of 30 feet. The wells are dug in glacial sediments, a till or hardpan lying above, with sand and gravel below. The wells afford excellent water, the flow rising to the surface in the wet season.

The water supply for Issaquah is furnished by the Gilman Water Company, which owns large springs near the town. The water is of good quality, there being no sources of contamination except possibly a little decaying vegetable matter. The water is conducted through the town by a gravity system. The few private wells in Issaquah range in depth from 20 to 30 feet, the water coming from a stratum of loose gravel. A large quantity of water may be obtained in this way, since it rises almost to the surface and is not affected by pumping. North of the town, toward Lake Sammamish, wells from 60 to 90 feet in depth have been driven, from which there is a continuous flow. The water rises from 3 to 10 feet above the surface.

The town of Kent gets its supply from springs which yield water of excellent quality. While the springs now drawn upon afford a supply for present needs, the product of other springs near by will be drawn upon in the future. From the springs the water is carried throughout the town by a gravity system. In the region about Kent good

water may be obtained by means of driven wells. The wells when driven to a depth of 200 feet are artesian in character, the water rising about 6 feet above the surface.

Water for Renton is obtained from a spring situated near the town limits and at a height of 320 feet above the level of the town. The spring belongs to the Seattle Electric Company, but the town has a lease upon it for fifty years. The spring supplies 120,000 gallons of water daily, and should this not be sufficient for future needs water may be obtained from other springs or from Cedar River, which flows through the town. The water, besides being used for domestic purposes, affords fire protection and furnishes the necessary boiler supply for a coal mine and a brickyard. The private wells in use in Renton are mostly shallow, ranging in depth from 10 to 25 feet. Only one enters rock, the others obtaining water chiefly from the gravels of the Cedar River flood plain.

The city of Seattle obtains its supply of water from Cedar River and Cedar Lake. The source of supply is in the Cascade Mountains, the water coming to the reservoir directly from the snow fields. The water is, therefore, soft, clear, and of superior quality. The city owns Cedar Lake and a large portion of Cedar River. The available water supply averages about 600,000,000 gallons per day. There are now piped to the city 22,500,000 gallons daily. Other supply mains will be constructed whenever they are found to be necessary.

A sanitary analysis of the city water of Seattle, made by Prof. H. G. Byers, of the University of Washington, on April 27, 1901, gave the following results:

Sanitary analysis of city water of Seattle.

[Parts per million.]

Total solids	36.49
Oxygen consumed	1.26
Chlorine	1.50
Nitrogen as free ammonia	.008
Nitrogen as albuminoid ammonia	Trace.
Nitrogen as nitrites	None.
Nitrogen as nitrates	None.

West Seattle obtains water from private wells and from some springs owned by the West Seattle Land and Improvement Company. The water is pumped into tanks, from which it is distributed by gravity. The supply even at the present time can hardly be said to be sufficient, and it is likely that arrangements will soon be made whereby water may be obtained from the Seattle system. The wells about West Seattle range in depth from 30 to 75 feet, water being most commonly found at about 50 feet. The wells are dug entirely in glacial material, mostly sand and gravel.

Springs.—Near the town of Berlin, in the northeastern part of the county, there is a mineral spring owned by the Everett Bottling Works. The water flows out as a stream from the base of a mountain of granitic rock. The flow is uniform from season to season. The quantity flowing has never been measured. The water has a taste of soda. No improvements of any character have been made at the spring, and so far no use has been made of the water. It is probable that in the near future a hotel will be built at the spring and other improvements made.

An analysis of water from the Berlin springs, made by H. G. Knight, of the University of Washington, is as follows:

Analysis of water from Berlin springs.

[Parts per thousand.]

Solids, nonvolatile	0.5473
Silica	.0078
Alumina and iron oxide	.0150
Calcium sulphate	.0529
Calcium carbonate	.5627
Magnesium chloride	.1693
Magnesium sulphate	.0935
Sodium sulphate	.9331
Potassium chloride	.0267
Carbon dioxide	1.4720

Near the town of Issaquah, at the head of a short, deep valley, is a large spring from which the water supply for the town of Issaquah is taken. The flow has not been measured, but there is sufficient water for a town of 1,000 inhabitants. The water is very clear, cold, and has a pleasant taste. It issues as a stream from a bed of gravel. No improvements have been made at the spring, and none are contemplated. The spring is owned by the Gilman Water Company.

Along the valley side, at the base of a steep hill near Kent, is a large spring from which the town supply of water is largely taken. The daily flow varies from 500,000 gallons in winter to 350,000 gallons in summer. The water is not appreciably charged with minerals, and is very clear and cold when it leaves the spring. It issues as a stream from a bed of gravel which is a part of the glacial sediments. At the spring a reservoir is now being built for storage purposes.

The Great Northern Hot Springs are located near Madison, in the northeast corner of the county. Near the Great Northern Railway, a mile from the springs, the Hot Springs Hotel has been built, with accommodations for 50 guests. The water is piped to the hotel, where it is used for drinking purposes and for baths. The water has been found to be very helpful for rheumatism and for kidney diseases. The water seeps out from the talus rock, and has a temperature of 122° F.

The following analysis of water from the Great Northern Hot Springs was made by C. Osseward, chemist for the Stewart & Holmes Drug Company, Seattle:

Analysis of water from the Great Northern Hot Springs.

[Grains per gallon.]

Total solids	9.9
Chlorine	.87
Iron	.76
Lime	2.33
Magnesia	1.1
Silica	1.34
Sodium	1.63
Potassium	.34
Sulphuric anhydride	.52
Ammonia	.00058

On a hillside near Renton there is a spring issuing from a bed of gravel. The flow is about 120,000 gallons daily. The quantity varies with the season, being about one-fourth less in a very dry season than in a wet one. The water does not carry any sediment, is very clear, and has a pleasant taste. It is used as a town supply by Renton.

KITSAP COUNTY.

General statement.—Kitsap County is situated east of Jefferson and Mason counties, west of King County, and north of Pierce County. It is almost surrounded by the arms or inlets of Puget Sound. With the exception of a range of hills in the southwestern part of the county, along Hood Canal, the surface is that of a plain lying but little above the sea. The coast line is very deeply indented and irregular, abounding in fine bays and harbors.

The rainfall gradually decreases from 60 inches per year in the southwestern part to 30 inches in the northeastern part. It is sufficient to give rise to the very many small streams which are to be found throughout the county and also to produce a very dense forest growth.

Over the major portion of Kitsap County the mantle of glacial sediments is very heavy, so that the bed rock does not often appear at the surface. The wells for the most part penetrate the glacial materials only, and from the latter a satisfactory supply of good water is obtained. As elsewhere within the glaciated area, springs are very common and are often utilized.

Municipal systems.—Bremerton obtains its water supply to a limited degree from wells, but for the most part from a stream which is fed by springs. In this way is obtained a supply of very good water, which is free from any contamination. The quantity will be ample

for a long time to come. Gravity is the system employed. The private wells, as a rule, are shallow and are sunk altogether in glacial till, the water flowing from intercalated beds of sand and gravel.

An analysis of water from a spring near Bremerton, made by H. G. Knight, of the University of Washington, is as follows:

Analysis of water from spring near Bremerton.

[Parts per thousand.]

Nonvolatile solids	0.45194
Silica	.01334
Alumina and iron oxides	.04764
Calcium sulphate	.046385
Magnesium chloride	.04008
Magnesium sulphate	.07790
Sodium sulphate	.23686
Lithium sulphate	.02128

The source of supply for Charleston is found in some springs and creeks west and south of the town. From these the water is carried to the town in wooden pipes. It is of good quality, and a quantity ample for present and future needs is easily obtained. The private wells about Charleston range in depth from 20 to 150 feet. These wells have been put down in glacial sediments and the water level rises and falls with the tide in the inlet near by.

The water supply for Port Blakeley comes primarily from a stream in the adjoining hills. A reservoir has been made, and from this, by means of gravity, the water is conducted to the town. There is a certain amount of decaying vegetable matter in the reservoir, and this causes some contamination of the water; otherwise the water is good, and sufficient in quantity to serve the town probably for a long time in the future. Besides this method of obtaining water, cisterns and wells are used to a small degree. These wells have a depth ordinarily of about 70 feet. Most of them are wholly in the glacial till, but some of them penetrate rock altogether, the water-bearing stratum in the latter case being a conglomerate.

Some small streams near Port Gamble are drawn upon for the water supply of that town. From reservoirs along these streams the water is distributed to the town by a gravity system. About 150,000 gallons of water are obtained daily, an amount sufficient for the present and the future. The water is soft and of good quality, no sources of contamination being present. Besides its use for domestic purposes, it is employed to a large extent as a boiler supply.

KITTITAS COUNTY.

General statement.—Kittitas County lies near the center of the State, between Chelan County on the north and Yakima County on the south, and extends from the summit of the Cascades eastward to

Columbia River. From the Cascade divide, which has a general height of about 6,000 feet above the sea, the country descends southeastward to a minimum elevation of 500 feet. In the northwestern part of the county the surface exhibits the usual ruggedness of the higher and wilder parts of the Cascades. The highest peak here, Mount Stuart, has an elevation of 9,470 feet.

The rainfall in Kittitas County varies widely because of the great difference in elevation from point to point. In the high mountains the precipitation is from 50 to 60 inches a year. It decreases eastward until it becomes less than 15 inches at Ellensburg and less than 10 inches in the vicinity of Columbia River. Naturally, the character of the vegetation is greatly modified by the wide variation in the amount of rainfall. The higher mountains as a rule are heavily forested, while the plateaus are sparsely covered with trees. In lower altitudes the trees give way to the bunch grass, which is in turn superseded by sagebrush on the still lower levels. The abundant rainfall of the mountains gives rise to many fine streams, which afford water alike for the use of cities on the plains below and for the irrigation of orchards and alfalfa fields.

The southeastern part of the county is largely covered by Miocene basalts. In the neighborhood of Ellensburg are remnants of a sandstone formation which represents the sediments of a middle Tertiary lake of unknown extent. The geology is somewhat complex, as both sedimentary and volcanic rocks of Eocene and Miocene age are found. The sedimentary beds are lacustrine, and consist chiefly of sandstone and shale. In one of the Eocene sedimentary formations round about the towns of Roslyn and Clealum, seams of coal of great economic value have been found, and here are the largest coal mines in the State. In the vicinity of Mount Stuart, near the southern border line of the county, there are large areas of pre-Tertiary rocks of a complex nature geologically, in which there are granites, granodiorites, serpentines, slates, and schists.

Municipal systems.—The water supply for Clealum comes from mountain springs about 3 miles southwest of town. The springs are 180 feet above the town, thus giving a good head and making it easy to distribute the water throughout the town by a gravity system. For the first mile from the springs a 10-inch pipe was laid, for the next mile an 8-inch pipe, and for the third mile a 6-inch pipe. The water pressure in the town is from 90 to 100 pounds per square inch. The amount of water obtained is believed to be ample for a city of 20,000 inhabitants. Should this supply ever fail, water in great abundance may be obtained from Yakima River, a clear mountain stream which flows through a part of the town. Clealum owns 160 acres of land about the springs, thus effectually preventing contamination. Some time ago an effort was made to obtain artesian water. A well

was drilled in Cleallum to a depth of 800 feet without striking water. The water supply of the town is used for irrigating as well as domestic purposes.

Ellensburg obtains water from streams which flow out from the foothills of the Cascades. The water obtained in this way, however, is not of the best quality and is barely sufficient for present needs. An unusual demand is made upon the supply, for a large amount of water is used for irrigation as well as for domestic purposes. The private wells which are in use range in depth from 10 to 20 feet. They are essentially surface wells, not entering the rock at all, but obtaining water from beds of gravel. The well water, as a rule, is hard and contains alkali. The water level in the wells varies, the water rising to the surface when the soil is thoroughly saturated as the result of excessive irrigation.

For its town supply Roslyn obtains water from Cleallum River, a mountain stream yielding water of excellent quality. This supply is so satisfactory that no dependence is placed upon wells, cisterns, or other sources.

KLICKITAT COUNTY.

General statement.—Klickitat County is situated on the southern border of the State, with Columbia River on the south, Yakima County on the north, and Skamania County on the west. The western part of the county is within the Cascades, and is therefore very rugged. The topography of the central part is that of a broad plateau sloping from the north toward Columbia River. The topography of the eastern end of the county is that of a plain rising but little above the level of the river.

In the western portion of the county the annual rainfall is from 30 to 35 inches, in the vicinity of Goldendale it is 15 or 20 inches, while in the eastern end of the county it is only about 10 inches. As a consequence of the unequal distribution of rainfall, the western portion of the county is a region of forests and streams; the central part has a very sparse forest growth and few streams, but at the same time is one of the best wheat-growing districts in the State; and the eastern part is treeless and virtually without streams, so that agriculture can be carried on only by means of irrigation.

With the possible exception of the extreme western end, all of the county may be said to be covered by Columbia River lava. The bed rock is basalt. As far as known, no deep wells have been drilled into it, as in other parts of the State, to determine whether or not it is water bearing. That it is water bearing is largely proved by the fact that in a number of places springs issue from the outcrops of porous basaltic rock. The springs in some instances have a temperature con-

siderably above that of the surrounding atmosphere. In some cases also they may be classed as mineral springs, and are believed to have medicinal qualities as well.

Municipal systems.—The water for Goldendale is piped from a spring on the southern slope of Simcoe Mountain, 12 miles to the north. The supply is sufficient for present needs, but will probably have to be increased in the future. Other good springs are conveniently near, and the water from these can be easily utilized. The water is soft and uncontaminated. The spring is located at a sufficient height above the city to give a good head of water. A few wells are used, ranging in depth from 12 to 75 feet. Most of the wells are shallow, water being most commonly found at 20 feet in beds of gravel. From the wells a large amount of water may be obtained. The water level shows but little change from season to season, and is affected by pumping only in a slight degree. In Goldendale a large amount of water is used in irrigation.

Springs.—On Government land in T. 6 N., R. 13 E., there is a large spring, or rather a group of springs. At these springs the water flows out in a stream from basaltic rock. The springs are located at the base of a bluff rising from the valley of Klickitat River. The flow is large, there being no perceptible variation from season to season. The water is clear and odorless, but it has an unpleasant taste. It has a temperature of 76° F. Bubbles of gas are constantly escaping from the water. It has been used to a limited degree for medicinal purposes.

On Big Klickitat River in T. 4 N., R. 14 E., is a spring which is considered to have special medicinal properties. By the internal use of the water, stomach and kidney diseases are benefited, and rheumatism is helped by bathing in the water. The spring issues as a stream from basaltic rock. It has a temperature of 100° F. There is a slight film on its surface and it carries a little sediment. It has a strong mineral taste and is charged with gas, iron, and sulphur. Deposits of iron oxide are made along the stream as it flows away from the spring. It is planned to make a health resort at this spring, and a hotel and bath house are in process of construction. An analysis of the water, made by Prof. H. G. Byers of the University of Washington, is as follows:

Analysis of spring water from near Big Klickitat River.

[Parts per million.]

Total solids	758.7
Nonvolatile solids	569.2
Volatile solids	189.5
Silica	85.5
Ferric oxide and alumina	104.9
Calcium carbonate	129.6

Magnesium carbonate	184.8
Calcium sulphate	4.5
Sodium chloride	10.1
Potassium chloride	22.3
Potassium sulphate	27.5
Free carbon dioxide	700.0

LEWIS COUNTY.

General statement.—Lewis County is in the southwestern part of the State and extends from the summit of the Cascades to Pacific County on the west, with Chehalis, Thurston, and Pierce counties on its northern border, and Wahkiakum, Cowlitz, and Skamania counties on the south. The county has a very diversified topography. The western end of it lies within the Coast Range, where the highest hills or mountains are from 2,000 to 3,000 feet in height. East of the Coast Range is a broad north-south valley which is in reality a part of the Puget Sound basin. East of this great valley rise the mountains of the Cascades, reaching heights of 5,000 or 6,000 feet on the main divide. The mountains have been greatly dissected by the streams, and some of the valleys, notably that of Cowlitz River, are very broad and deep.

The rainfall is heaviest in the western part of the county, where it averages 70 inches per year. It decreases eastward until in the neighborhood of Chehalis and Centralia it is 50 inches. In the mountains of the eastern part of the county the average yearly rainfall is 60 inches. This heavy rainfall gives rise to a very large number of streams and produces a luxuriant forest growth which is equal to any found elsewhere in the State.

The eastern part of the county, or that within the Cascades, is practically unknown geologically. There are a few small areas of coal-bearing sandstones and shales lying along the upper Cowlitz River and in the region about Cowlitz Pass. The geology of the western two-thirds of the county has been studied to some extent, and as far as known the rocks are of Eocene age. Fossils of marine Eocene types occur in great abundance along the Cowlitz in the vicinity of Little Falls. The sedimentary rocks are mainly sandstones and shales and are coal bearing at a number of places, notably about Chehalis and Centralia, in the vicinity of Alpha and Cinebar, and near Morton. Upon the sedimentary rocks in most places a deep soil has formed, and within this water is obtained with ease by means of shallow wells. Springs are common upon the hillsides, and they may be regarded as important sources of good water. The amount of surface water to be had is so very large that it is not probable that recourse to deep wells will ever be necessary. The structure of the sedimentary rocks is such that they undoubtedly contain artesian basins, which may be tapped whenever the need arises.

Municipal systems.—The water for Centralia is obtained partly from wells and partly from Skookumchuck River. From neither of these is very good water obtained, and some other source must be sought out. The wells range in depth from 20 to 30 feet. Water is most commonly found at about 18 feet, in beds of gravel, but as these beds are not overlain by clay or other impervious material, contamination from the surface is not prevented. From these wells a large supply of water may be obtained. The water level varies but little during the year, being somewhat lower in the dry season.

The water supply for Pe Ell is obtained mostly from wells, although a few families derive their supply from springs. The spring water is satisfactory, but the same can hardly be said of the wells. The latter are very shallow and contamination from the surface is very easy. The well water comes from gravel and rises to the surface in some cases. A large supply of water is had, the water level scarcely varying during the year.

LINCOLN COUNTY.

General statement.—Lincoln County is in the eastern part of the State and is bounded on the east by Spokane County, on the west by Douglas County, on the south by Adams County, and on the north by Columbia and Spokane rivers. The surface is that of a plateau having a general height of about 1,500 feet above sea level. On the north the plateau slopes very abruptly to the canyon of the Columbia, while on the south there is a gentle slope toward Crab Creek. Low, rolling hills occur here and there.

The yearly rainfall varies from 10 inches in the western half to 15 inches in the eastern portion. This is too small to permit of forest growth and hence the county was formerly a prairie region clothed with grasses. The bunch grass now, however, has largely given way to wheat fields, and the county produces each year an increasing amount of grain. The streams are in the main of the intermittent type, there being but very few that are of a permanent character. The small streams are active in the runways during the winter and spring months only and disappear with the coming of summer.

With the exception of the outcrops of granite in the vicinity of Columbia and Spokane rivers the bed rock is altogether basalt. The basalt has within it porous layers which become filled with water, thus forming important reservoirs. In the ravines and "coulees" the porous basalt often outcrops and gives origin to springs which afford an ample quantity of water for general house and farm use. As a rule, the springs are active all the year, and in some instances have a flow sufficient for use as a municipal supply. In cases where springs have not been available wells have been dug in the basalt, and

whenever the porous rock was encountered ample supplies of water were obtained. Ordinarily the wells vary in depth from 25 to 50 feet.

Municipal systems.—Water for Davenport is obtained from springs near the town. The supply is sufficient for present needs, but it is probable that it will have to be increased. The water is of good quality and there are no sources of contamination. A gravity system of waterworks is used. The wells in the region vary in depth from 20 to 60 feet, the water being most commonly found at 30 feet. The wells enter the rock, and a layer of clay at the surface prevents any contamination from that direction. No flowing wells have been found, but a large supply of water is obtained from the common wells. The water level does not vary during the year and is not affected by pumping. Much water is used in irrigation as well as for domestic purposes.

Harrington obtains its water from wells, although springs are used to some extent. The wells vary in depth from 30 to 100 feet. Water is most commonly found at about 35 feet. All of the wells enter basalt. The water usually rises to within 20 feet of the surface, where it stands constant the year round. It is of good quality, but will doubtless be insufficient for future demands. The water is pumped into a standpipe and distributed by gravity.

The supply for Sprague is obtained in part from a spring and in part from wells. At the spring the water issues from basaltic rock and varies much in quantity from season to season. During the dry season the supply from the spring becomes insufficient and the wells are relied upon. The supply from the wells seems to be inexhaustible and constant pumping makes no impression on the water level. The water from the spring is distributed by gravity, while the well water is obtained by pumping. From these sources excellent water is obtained in quantities believed to be sufficient for all future needs. The private wells of the region vary in depth from 20 to 40 feet. Water is commonly found at a depth of 20 feet. These wells do not enter rock, but are wholly in surface material. The water-bearing materials are sand and gravel. The wells, although shallow, afford a large quantity of water, the level being lowered only in a long, dry season.

Water for Wilbur is obtained from Goose Creek, which has its source in two large springs, and also from some wells. The water is of good quality, and ample in quantity for present and future needs. A gravity system of waterworks has been installed. The wells are all very shallow, the usual depth being about 12 feet. They enter the basaltic rock which underlies the town. Contamination from the surface is prevented by a layer of clay. The wells, although shallow, are relied upon for the domestic supply, and the water from the springs is used largely in irrigation.

Springs.—In sec. 21, T. 25 N., R. 37 E., near the town of Davenport, there is a large spring from which about 360,000 gallons of

water flow daily. This supply is fairly constant, although slightly less in summer. The water is clear and cold and has a pleasant taste. It issues as a stream from the rock. It is used as a water supply for the town of Davenport.

Near Davenport, on the farm of J. E Ludy, there is a spring which is located in the bottom of a deep draw or gulch. The water comes out as a stream, and in quantity sufficient to supply about 15 families. It is slightly alkaline, but there are no deposits of mineral matter or sediment about the spring. The water has a temperature of about 45° F.

Near Harrington, in sec. 34, T. 23 N., R. 36 E., there is a spring owned by J. L. Ball. The water issues from the rock at the base of a bluff. It is clear and of a very good quality. It is used for a general farm supply.

L. T. Luper owns 2 springs near Harrington, in secs. 1 and 9, T. 23 N., R. 36 E. The spring in section 1 flows about 23,000 gallons per day, and the one in section 9 about 28,000 gallons per day. Neither spring shows any variation in flow from season to season, and in both the water is clear, of good quality, and apparently not mineral bearing. In each case the water issues as a stream. The water is used as a house supply and in watering stock.

Near Sherman, in sec. 25, T. 29 N., R. 33 E., H. B. Fletcher owns a spring which appears as a stream. The spring is located in a valley. The flow is very large and is constant from season to season. The water as it issues is cold, clear, and of a superior quality. It is used by the farmers for their stock, but it has been proposed to pipe the water to Wilbur as a supply for that town.

MASON COUNTY.

General statement.—Mason County lies in the western part of the State, being separated from the Pacific Ocean by Chehalis County, which borders it on the west. It is bounded on the north and northeast by Jefferson and Kitsap counties, and on the southeast and south by Pierce and Thurston counties. The northwestern portion of the county extends into the Olympic Mountains, and hence is very rugged and broken in character. Most of the remaining part of the county is very hilly, the only portions that are level to any degree being those immediately about Hood Canal and other inlets of Puget Sound. The streams which come from the mountains flow in canyons, and the interstream divides are very sharp.

The yearly rainfall is very heavy, ranging from 85 inches on the western border to 60 inches in the extreme eastern portion. As one result of the copious rainfall there is a heavy forest growth, the forests of Mason County being regarded as among the best in the State. In the southeastern part of the county, the only portion which is set-

tled to any extent, water for domestic purposes is obtained very largely from the glacial deposits, which are here very thick. As a rule the wells are shallow, water being obtained at depths varying from 10 to 25 feet. With the abundant rainfall and the heavy mantle of unconsolidated surface materials it is not surprising that springs are very common. The water issues from the springs in the form of streams, and usually in sufficient quantities to afford town supplies.

Municipal systems.—The water supply for Shelton, a town of about 1,000 people, is obtained from some large springs, and will doubtless prove inadequate when the population of the town is doubled, but there are other large springs located conveniently near which may be utilized. The water is soft and pure and very satisfactory for domestic purposes. A gravity system of waterworks is used. In the region about Shelton there are a good many wells from which excellent water is obtained. In some instances the water rises to the surface, and the water level is not distinctly lowered except in September, the month of the least rainfall. The wells are as a rule driven wells, the materials penetrated being glacial till, sand, and gravel. The wells are shallow, varying from 10 to 25 feet in depth. The water-bearing material is overlain by hardpan, so that there is no contamination from the surface.

Springs.—As noted above, the town of Shelton obtains its water supply from two springs located in sec. 12, T. 20 N., R. 4 W. The flow has not been measured, but it is ample for all present demands. The springs issue as streams from gravel beds which outcrop on a hillside above the town. The water contains a small amount of iron, but there are no deposits of mineral matter about the springs.

At other places about Shelton, notably in sec. 18, T. 20 N., R. 3 W., and in sec. 13, T. 20 N., R. 4 W., are other springs which supply large quantities of water. They issue from gravel beds at the base of a bluff about 150 feet high. From the top of the bluff a gravel terrace extends for several miles. Lying upon this terrace, near the springs, there are several lakes, and it has been suggested that the lakes are the sources of the spring water.

OKANOGAN COUNTY.

General statement.—Okanogan County extends from the British Columbia line to Columbia River, and from Ferry County on the east to Chelan and Whatcom counties on the west. This large county presents a great diversity of surface, and within it are rugged mountains, rolling hills, and broad plateaus which merge into plains. The western portion of the county is a region of high mountains and deep valleys. Between Methow and Okanogan rivers is a bold mountain ridge which has a north-south course. Along the eastern border line of the county

there is likewise a mountain ridge, with a north-south course and a general height of about 4,000 feet above the sea. Along the southern border of the county the Columbia flows in a deep canyon, but the Okanogan, its chief tributary, is a meandering stream flowing in a broad and comparatively shallow valley. The Methow Valley is likewise very broad and open, except for the last few miles of its course, when it assumes a canyon aspect.

The rainfall of Okanogan County is light in comparison with other parts of Washington. In the mountainous area the annual precipitation is from 15 to 20 inches. Over much of the remaining part of the county it ranges from 10 to 15 inches, and over a small portion it is even less than 10 inches. The forest grows exclusively upon the highlands, chiefly in the Cascades, in the mountains along the eastern border, and on the mountain ridge between Okanogan and Methow rivers. Over those parts of the county where the trees can not grow bunch grass abounds, only the lowest plains along Okanogan River being given over to sagebrush. From the mountains good streams of water flow to the plains and make possible irrigation on a large scale in the valleys of Methow, Okanogan, and Columbia rivers.

As far as known the rocks of Okanogan County are chiefly gneisses, schists, slates, and crystalline limestones. Here and there are small remnants of more or less extensive sediments of Tertiary lakes. Over large areas intrusive and extrusive igneous rocks of various kinds prevail. Over much of the surface there is a thick mantle of soil, and within this in most places water may be obtained by means of wells. Springs commonly occur, and they are relied upon to a large degree by the settlers. Surface water is usually sufficiently abundant to supply the herds of cattle and sheep with their requirements.

Municipal systems.—Loomis obtains its water from Sinlahekin Creek and from a spring owned by J. M. Judd. Neither source is very satisfactory, and it is planned to secure a supply from Toats Coulee Creek, a mountain stream of pure water which flows near the town. A few wells have been dug in the district about Loomis. They are all shallow, ranging in depth from 20 to 30 feet. They do not reach bed rock, but lie wholly in the mantle rock or soil.

PACIFIC COUNTY.

General statement.—Pacific County lies at the southwest corner of the State. The ocean border of the county is exceedingly irregular, due in part to a submergence of the coast and in part to the building out from the headlands of long sand spits. The surface rises gradually from tide water to the summit of the Coast Range, where a maximum height of 3,000 feet above the sea is attained. Much of the coast is low, and alluvial valleys extend for some distance up the

streams. The annual rainfall is very heavy, varying from 65 inches at the mouth of the Columbia to 85 inches and over along the northern border. In this county the change in amount of precipitation is in a north-south rather than an east-west direction as is commonly the case. As elsewhere the large rainfall produces many streams and an extraordinary forest growth. The larger trees are closely surrounded by a very dense growth of minor forms, so that the forest as a whole is almost impenetrable.

With few exceptions all the rocks of the county are shales, sandstones, and conglomerates of middle Tertiary age. All of these disintegrate readily when exposed to the atmosphere, so that there is a heavy mantle of incoherent porous material many feet in depth. Within this soil there is generally an abundance of water, so that shallow wells and springs form the main sources of domestic supply.

Municipal systems.—Springs afford the water supply for Ilwaco, but they are not very satisfactory and in the near future some other source must be sought. The present supply is not of the best quality and will soon be inadequate. Contamination is due chiefly to decaying vegetable matter. A gravity system of waterworks is used. Ilwaco is situated on a plain which rises but little above high tide. Wells are not used at all, because the water within them is unfit for drinking purposes.

The supply of water for Southbend is obtained from springs. In this way water of excellent quality is had, free from contamination, and in quantity believed to be sufficient for all future needs. The water is carried from the springs and distributed about the town by a gravity system. Very few wells are used about Southbend, and in none of them is the water satisfactory. The wells vary in depth from 10 to 60 feet.

PIERCE COUNTY.

General statement.—Pierce County extends from the summit of the Cascades on the east to Puget Sound on the west, and from King and Kitsap counties on the north to Lewis and Thurston counties on the south. In the vicinity of the sound the surface is that of a plain with a general height of 300 to 400 feet above sea level. Eastward the plain gives way to hills, which in turn soon merge into the high mountains forming the eastern third of the county. Mount Rainier lies in Pierce County, and immediately about it and to the northeast high peaks and deep valleys are very conspicuous.

The lowest annual rainfall is in the neighborhood of Tacoma, where it averages 45 inches. It increases eastward and in the mountains is about 60 inches. Upon the sides of Mount Rainier and the neighboring high mountains the precipitation is principally in the form of snow, and large snow fields and glaciers are found. By the precipitous

descent of many of the large streams waterfalls of much economic importance have been produced. Some of the waterfalls are now being utilized for power purposes. The heavy rainfall of the mountains insures an ample supply of the purest water for the cities about the sound or upon the plains.

In the region about Burnett, Wilkeson, Carbonado, and Fairfax the outcropping rocks are chiefly clastic sediments of Eocene age. They are coal bearing, and at the places above mentioned coal mines are now in operation. The extent of the sedimentary series is unknown, since eastward it passes under the lavas of Mount Rainier and westward it disappears beneath the heavy mantle of glacial sediments which covers the western third of the county. The glacial deposits for the most part are made up of coarse gravels and sands, into which the water sinks after each rainfall, so that the drainage is chiefly underground. In the western part of the county there are but few streams save those which have their origin in the hills and mountains. Ordinarily a large quantity of good water is obtained in wells having a depth of 40 to 50 feet. Springs are very abundant and it is from this source that the principal towns of the county derive their water supplies. The springs are commonly found at the bases of the hills, and from them the water usually issues in the form of streams. Not only are the springs numerous, but the quantity of water that flows from some of them is phenomenal.

Municipal systems.—A well situated on an island in White River, near the town, supplies Buckley with water. From this source, by pumping, a very large supply may be obtained, ample for present and future needs. The water is of good quality, there being no known sources of contamination. In the region about Buckley the wells vary in depth from 30 to 40 feet, the water-bearing materials being beds of sand and gravel. The latter are overlain by glacial till or hardpan, so that the wells suffer no contamination from the surface.

The water for Carbonado is obtained from springs located in some gravel beds overlying the coal-bearing rocks. The supply is sufficient for the present and doubtless will be enough for all future needs. A gravity system of waterworks is in use. The water is used for boilers as well as for domestic purposes. There are no wells in Carbonado.

Springs furnish a supply of water for Orting. The water is not contaminated and is very satisfactory. The supply is ample for all the demands made upon it. Other springs near by may be utilized if necessary. A gravity system of waterworks is used. In the region about Orting are a few wells, their depths varying from 14 to 18 feet. The wells are wholly in glacial materials, not reaching the bed rock in any case. The water in the wells is excellent and abundant, usually rising to the surface in the winter months.

The water used in Puyallup comes from Maplewood Springs.

These springs lie within the city limits and have a flow of 20,000,000 gallons daily. The water is of good quality. It is distributed through the town by a gravity system. Puyallup is located on the flood plain of Puyallup River near where it enters the sea. The wells that have been dug in the alluvium of the valley do not yield good water and hence are rarely or never used.

The water system in South Tacoma is owned by Calvin Phillips & Co., who obtain a daily supply of 150,000 gallons from wells. The water is free from any contamination and is quite satisfactory. The usual depth of wells about South Tacoma is 40 to 50 feet. The wells penetrate beds of gravel and sand and in no instance reach bed rock.

For Sumner the water is obtained from a spring located on a hillside 1 mile east of the town. The spring is sufficiently above the level of the town to give a good head to the water, so that it may be distributed by gravity. The supply is ample for present needs, and there are other good springs near by which may be utilized in the future should the needs of the town so demand. No wells are used in the valley about Sumner, all of the water for domestic purposes being piped from the springs on the hillsides which border the valley.

The city of Tacoma obtains its water supply from Clover Creek and some springs. From the former the major portion of the water used in the city is obtained, but the spring water is more satisfactory. The quantity obtained is hardly sufficient for the needs of the city and, as additional sources of supply, three deep wells are being drilled. From the creek and springs water is pumped into reservoirs, from which it is distributed by gravity throughout the city. Tacoma is located upon a plain composed of glacial sediments, till, clay, sand, and gravel, which yield an abundant supply of good water. The depth of the wells varies from 30 to 100 feet. In general the water-bearing strata are overlain by clay or till, so that surface contamination is reduced to a minimum.

A sanitary analysis of water from Clover Creek and springs, made February 23, 1901, by Prof. H. G. Byers, of the University of Washington, resulted as follows:

Analysis of water from Clover Creek and springs.

[Parts per million.]

Total solids	47.20
Nonvolatile solids	25.20
Volatile solids	22.00
Oxygen consumed	6.34
Chlorine	4.40
Nitrogen as free ammonia	.035
Nitrogen as albuminoid ammonia	.080
Nitrogen as nitrites	None.
Nitrogen as nitrates	None.

Springs.—Near the town of Carbonado, in sec. 4, T. 18 N., R. 6 E., the water issues as a stream from some gravel beds which overlie the coal measures at this place. The spring yields sufficient water to supply the town of Carbonado and the boilers of the Carbon Hill Coal Company.

The Orting Light and Water Company own three springs in sec. 29, T. 19 N., R. 5 E. These springs are small, but afford enough water to supply the town of Orting. They are located upon a hillside, where the water issues as small streams from beds of sand and gravel. The water carries a little sand and is somewhat muddy after hard rains. The flow is said to be a little stronger in summer than in winter.

Maplewood Springs are located near Puyallup, in sec. 32, T. 20 N., R. 4 E. The water issues in streams from beds of gravel at the base of a bluff. The flow is estimated at 20,000,000 gallons per day. The town of Puyallup and a portion of Tacoma are supplied with water from this spring. The spring is owned by the city of Tacoma.

SAN JUAN COUNTY.

General statement.—San Juan County comprises a group of islands lying between Whatcom and Skagit counties in Washington and the island of Vancouver. These islands have rocky, irregular, deeply indented shores and represent the tops of submerged mountains. The surface of some of the islands is that of a plain, but in most cases there are high hills or semimountains. The principal hills are on Orcas Island, the highest point, Mount Constitution, rising 2,200 feet above the sea.

Since the San Juan Islands lie to the leeward of the mountains of Vancouver Island, they have a rainfall that is less than the average of western Washington. The yearly rainfall is between 30 and 35 inches. This is enough to support but a moderate forest growth, so that the trees are not so large as in some parts of the State and there is but a small amount of undergrowth. The rainfall is ample for agricultural purposes and excellent crops are raised.

The rocks of the northernmost islands of the group are of upper Cretaceous age and are a part of the coal-bearing series of the islands of British Columbia. South of the sedimentary rocks just mentioned, and forming the major portion of the islands, are metamorphic and igneous rocks of undetermined age. All of the islands have been glaciated, and oftentimes the rocks are deeply furrowed. The glaciers laid bare the rocks in some instances, and over much of the surface but a thin soil was left. The area of tillable land is thereby largely reduced and limited to the lower valleys. On a few of the islands the water supply is scant and the problem of securing water for domestic

purposes is a difficult one. Only a meager supply of surface water is obtained because of the scant rainfall. The slight depth of soil makes it necessary to dig the wells in bed rock in most places. In some instances, however, as about Friday Harbor, the soil is of sufficient depth to yield a water supply by means of shallow wells.

Municipal systems.—The water supply for Friday Harbor comes altogether from wells. These yield water of good quality, which thus far has been quite satisfactory. The wells are all shallow, not often reaching a depth exceeding 18 feet. The water is obtained from beds of gravel. These are overlain by clay, thus preventing surface drainage from entering the wells. A good water supply for the town of Friday Harbor can be had in Sportsmans Lake, which is 3½ miles away and lies at an elevation of about 75 feet above the town. The lake covers 90 acres and is fed by springs.

SKAGIT COUNTY.

General statement.—Skagit County is in the northwestern part of the State and lies between Whatcom County on the north and Snohomish County on the south. It extends from Puget Sound on the west to the summit of the Cascades on the east. The coast is very irregular. The topography of the western part of the county is that of a plain lying but little above the sea. The eastern half is very rough and broken and embraces some of the most rugged portions of the Cascades. A prominent feature of the surface is the great valley of Skagit River, which has an east-west course through the county and upon the broad delta of which the principal towns are located. Dikes have been built along the coast and the lower reaches of the river to keep the alluvial plain from being overflowed. The tide runs up Skagit River for about 20 miles.

The yearly rainfall varies from 30 inches along the coast to an average of 50 inches in the mountains. Practically all of the region was once forest covered, and the cedars of the Skagit Valley are among the largest and best to be found in the State. The timber of the broad alluvial plain along the lower course of the river has been largely removed and excellent farms have taken its place. The most valuable farm land in the State is found here, the amount of rainfall and the excellent quality of the soil being conducive to very high agricultural returns.

In the region south of Hamilton and immediately about Cokedale are outcropping Tertiary sandstones and shales which are coal bearing and in which coal mines have been opened. The extent of these sedimentary areas is unknown, since they are largely concealed by the alluvial deposits of the river, glacial sediments, etc. East of

Hamilton is a north-south belt of slates and schists containing small bodies of iron ore. Among the islands at the western end of the county are frequent outcrops of slates, schists, and other metamorphic rocks. Along the borders of the valley of the lower Skagit are thick deposits of glacial sediments, from which water is often obtained by means of wells and springs. The towns located in the valley of the Skagit may secure supplies of water either from the springs on the adjacent hillsides or from shallow wells that have been sunk into the sands and gravels of the river plain.

Municipal systems.—The town of Anacortes obtains its water from Lake Heart, which is fed by springs. The lake is about 250 feet above the town, so a gravity system of waterworks is used. Lake Heart, although now supplying enough water for the use of the town, will in time become inadequate. Other desirable sources of supply may easily be found in Cranberry and Whistler lakes, which lie near the town. The water now used is of good quality and is quite satisfactory. Some of the wells of the region are shallow, but the best water is obtained at a depth of about 80 feet. Not even the deepest wells enter bed rock, the materials passed through being clay above, with beds of gravel below.

Hamilton secures its water supply exclusively from wells. These are shallow, since the town is located on the flood plain of Skagit River. The wells range in depth from 10 to 25 feet. The height of water in the wells depends upon the stage of water in the river. The water in the wells all comes from the river by seeping through the coarser materials of the flood plain. In each well a lateral movement of the water in the same direction as the flow of the river may be readily seen.

The water that is used at Laconner is brought from a spring by a gravity system. The water is of good quality, and is ample in amount for present demands, but may need to be supplemented in the future.

Water for the use of the town of Mount Vernon is obtained from a large spring. From the spring water is pumped into a reservoir located on a hill above the town and is then distributed by gravity. The water is very pure, there being no sources of contamination, and it is sufficient in amount for present and future needs. The wells of the region range in depth from 10 to 14 feet. They do not enter bed rock, but are altogether in the alluvium of the valley. In some instances the well water is not of good quality.

SKAMANIA COUNTY.

General statement.—Skamania County lies on the southern border of the State, south of Lewis County, between Yakima and Klickitat counties on the east and Cowlitz and Clarke counties on the west. The proportion of low plain to high mountain is less than in any other county in the State. With the exception of a very narrow plain along Columbia River the entire county consists of rugged mountains which have a general height of about 5,000 feet above sea level. From east to west the county covers very nearly the entire width of the higher Cascades in this part of the State. The highest point is Mount St. Helens, with an elevation of about 10,000 feet, standing near the northern border line. St. Helens is a volcano that is said to have shown slight signs of activity since white settlers first came to Washington. It has suffered but little erosion and is symmetrical in outline.

The rainfall ranges from 60 inches or a little more in the northwestern part to 40 inches on the southeastern border. The elevation is such that the rainfall is heavy. It should be noted, however, that not all of the precipitation is in the form of rain, but that some of it, especially in the northwestern part of the county, is in the form of snow. With the exception of a few mountain peaks the surface is entirely forested, and over one-half of the county is within the limits of the Mount Rainier Forest Reserve.

Little is known of the geology of the county. Nothing but basalt, presumably belonging to the Columbia River lava, appears along Columbia River. About 15 miles north of the river, northeast of Skye, outcrops of granite occur. These outcrops are believed to be at the southern end of a belt of granite which runs northward through the county, passing between Mount St. Helens on the west and Mount Adams on the east. The warm springs which occur at Cascades seem to indicate that there are igneous rocks at moderate depths in that vicinity which are not yet entirely cooled. Very little information is at hand regarding the details of the water resources of the county, since it is very sparsely peopled. The only settlements are located in the immediate vicinity of Columbia River.

Springs.—Near Cascades post-office, on Columbia River, in sec. 16, T. 2 N., R. 7 E., is a mineral spring owned by Thomas Moffett. The water seeps out at the base of a hill, and flows 25,000 gallons daily, with no variation from season to season. The water has a temperature of 96° F. Gas is constantly escaping and the water is known to carry iron and sulphur. At the spring a bath house and a hotel of 25 rooms were erected some years ago. Plans have been drawn for a new hotel of 100 rooms, new bath houses, and a swimming tank 60 feet long, 20 feet wide, and 7 feet deep. The water is of medicinal value,

being especially healthful in diseases of the stomach and kidneys. The water is bottled and placed on the market, $1,200 worth having been sold in 1902.

SNOHOMISH COUNTY.

General statement.—Snohomish County is located in the northwestern part of the State, between Skagit County on the north and King County on the south, and extends from the summit of the Cascades to the shores of Puget Sound. The surface of the western third of the county is that of a low plain either level or covered with low hills. The eastern two-thirds has a mountainous topography, varying from the low foothills on the west to the lofty snow- and ice-covered peaks on the main divide. The mountains have been trenched by Skykomish River and the North and South forks of the Stilaguamish, all of which flow in deep valleys. These rivers have in general a westerly course, and the watersheds are separated by bold spurs which extend outward from the main mountain mass.

There is a considerable difference between the rainfall of the lowlands along the coast and that in the high mountains. Along the western border of the county the annual rainfall averages 35 inches; at the foothills of the mountains it is 50 inches; while within the mountains, and especially toward the eastern summit, it reaches 60 inches and over. In the vicinity of Monte Cristo, about Glacier Peak, and elsewhere in the high mountains the snowfall is very heavy and great fields of snow and many glaciers are the result. With the exceptions of the high mountains that are covered with snow or ice, or are barren of soil, almost all parts of the county are heavily forested. The best timber is found on the plains and the low hills in the western part of the county and in the larger valleys of the mountains. The northeastern part, embracing over a third of the county, is included in the Washington Forest Reserve.

In the western end of the county the bed rock appears at very few places because of the great thickness of the glacial sediments. There are a few outcrops of Tertiary sandstones and shales, which are not coal bearing, as far as observed. The mountainous portion is composed of a great complex of metamorphic rocks with many varieties of extrusive and intrusive igneous rocks. The water supply of the county is obtained in part from the mountain streams and in part from the glacial deposits, in the latter case either from springs or by means of wells. The several sources afford a very satisfactory supply, and there is no part of the county that is not abundantly provided with water of the finest quality.

Municipal systems.—The town of Arlington secures water from springs, wells, and Stilaguamish River. Both springs and wells are

very satisfactory, a large supply of excellent water being thus obtained. The wells vary in depth from 20 to 30 feet. They do not enter the rock, but have been dug wholly in clay, sand, and gravel.

Edmunds secures its town supply of water almost wholly from springs, only a few wells being in use. The springs yield a supply that is satisfactory in both quality and quantity. A gravity system of waterworks is used.

Everett obtains a supply of water from 2 creeks, one flowing within a mile and the other within 2½ miles of the city. From these streams the water is conveyed through pipes of 22 and 8 inches in diameter to a reservoir which has the capacity of 1,200,000 gallons. From the reservoir the water is distributed by a gravity system throughout the city. The water is free from contamination and highly satisfactory in every way. The wells in the region about Everett vary in depth from 15 to 115 feet, water being usually found at about 100 feet. The materials penetrated are surface soil, glacial till or hardpan, and finally sand or gravel, which yield the water. Bed rock is not reached even in the deepest wells. A large supply of good water may be obtained from the wells, which is ample in quantity for domestic demands. The following sanitary analysis of the city water of Everett was made by Prof. H. G. Byers, of the University of Washington, on January 10, 1901:

Analysis of city water of Everett.

[Parts per million.]

Total solids	300.80
Nonvolatile solids	252.80
Volatile solids	48.00
Oxygen consumed	7.27
Chlorine	4.80
Nitrogen as free ammonia	0.020
Nitrogen as albuminoid ammonia	0.050
Nitrogen as nitrites	None.
Nitrogen as nitrates	None.

In Marysville the water supply comes exclusively from wells. The wells are all shallow, since the town is located on the flood plain of Snohomish River. The water is soft, of good quality, and satisfactory for the present, at least. It is planned to use at some future time the water of Lake Stephens, which is located conveniently near.

The water supply for Monroe is obtained from two small creeks. In this way very pure water is had, and in quantity sufficient for present and future needs. A gravity system of waterworks is in operation. The wells are from 18 to 50 feet in depth. None of them enter rock, all being wholly within the alluvial materials of the river valley. An analysis of water from the Monroe supply was made by G. L. Tanzer, of Seattle, on August 3, 1903. He found that there was 0.049 grain of solid matter in 1 liter (33.81 fluid ounces) of

water. A qualitative analysis of the solid matter showed it to contain magnesium and sodium chlorides, with a trace of calcium carbonate. No ammonia, nitrogeneous matter, iron, or silicates were found.

Monte Cristo obtains a water supply from a mountain stream, using a gravity system. The water comes directly from the snow fields near by and is very cold and pure. The quantity is greater in autumn and spring than in other seasons, but probably will always be equal to every demand. Besides its uses as a domestic and boiler supply it is also used in an ore concentrator.

The water supply of Silverton comes from mountain streams which head in the fields of snow and ice near the town. The water is therefore of exceptional purity and may be had in quantity sufficient for all possible needs. It is used as a domestic supply, for water power, and in concentrating ore.

Snohomish secures its supply from Pilchuck River, a stream heading to the east in the Cascade Mountains. The water is pumped into a reservoir having a capacity of 500,000 gallons and is then distributed by gravity. There are no sources of contamination and the water is of good quality. The quantity is sufficient for all future needs. The wells about Snohomish range in depth from 15 to 55 feet. In digging the wells glacial till or hardpan is first passed through, and the water is obtained from the beds of gravel that lie below. The following sanitary analysis of water from the city supply was made by Prof. H. G. Byers, of the University of Washington:

Analysis of city water from Snohomish.

[Parts per million.]

Total solids	41.50
Nonvolatile solids	23.22
Volatile solids	18.28
Oxygen consumed	3.75
Chlorine	4.00
Nitrogen as free ammonia	.010
Nitrogen as albuminoid ammonia	.093
Nitrogen as nitrites	None.
Nitrogen as nitrates	.400

SPOKANE COUNTY.

General statement.—Spokane County lies in the extreme eastern part of the State, with Stevens County on the north, Lincoln County on the west, and Whitman County on the south. In the main the surface is that of a plateau, with an average height of about 2,000 feet above the sea. The only exceptions to the plateau aspect to be noted are the mountains in the northeast corner, of which Mount Carlton is the highest, and the high hills or low mountains in the south-

eastern part along the Idaho boundary. The principal stream, Spokane River, flows in a broad, shallow valley from the eastern border of the county to the city of Spokane; at this point it enters a canyon, of very moderate depth at first, but gradually deepening as the river flows northwestward to join the Columbia.

The average rainfall is about 20 inches per year. The precipitation on the western border is somewhat less than this, while on the eastern side it is a little more. The result is that in a general way the eastern half of the county is forested, while the western half is a prairie. The grassy plains have been largely replaced by wheat fields, since the rainfall is always ample to secure a crop of this cereal. The forest growth is rather sparse, the trees are of only moderate size, and there is little undergrowth.

Spokane County lies partly within the Columbia River lava field, the bed rock of the southwestern half being basalt. As this is the border line of the lava field the basalt is comparatively thin and the underlying rocks occasionally appear through it. The northwestern part of the county is chiefly a granite region, with occasional areas of gneiss and schist. Among these rocks basalt often appears in the form of narrow tongues which have extended outward from the main mass of lava. The valley of Spokane River in Glacial time was almost entirely filled by a gravel train, only a minor portion of which has been removed. At Spokane Falls is a jutting ledge of basalt, and the river drops 130 feet. Within the gravels and sands of the river valleys good water is obtained by means of deep wells. Upon the lava plateau domestic supplies of water are secured from wells ranging from 30 to 135 feet in depth. Some of the basalt is porous, and where such rock outcrops along the bases of hills springs are often found.

Municipal systems.—Cheney obtains a water supply from a lake and from wells. The lake supply is the more commonly used, but water from the wells is more satisfactory. An ample amount is secured for the present and doubtless for all future needs. A direct pressure system of waterworks is in use. The wells vary from 30 to 50 feet in depth, water being most commonly found at 40 feet. They all enter basalt after passing through a layer of clay at the surface. Very good water is secured. The water level scarcely varies from season to season, and is not affected by pumping.

The town of Medical Lake secures water from Clear Lake, located 3¼ miles to the south. The water is hard, but quite satisfactory otherwise. A supply sufficient for all possible demands may be obtained. In the wells about Medical Lake water is usually found at a depth of 15 feet; but the range of depth of the wells is from 10 to 40 feet. The wells are all in basalt, the porous or scoriaceous layers of the rock being water bearing.

An analysis of the water of Medical Lake, made by G. A Mariner, of Chicago, is as follows:

Analysis of water of Medical Lake.

[Parts per thousand.]

Silica	0.1825
Alumina and iron oxide	.0120
Calcium carbonate	.0031
Magnesium carbonate	.0040
Sodium chloride	.2869
Potassium chloride	.1616
Sodium carbonate	.1089
Potassium carbonate	Trace.
Lithium carbonate	Trace.
Borax	Trace.

Hillyard obtains a supply of water from deep wells. These are commonly from 190 to 200 feet in depth and are wholly in gravel. The water is soft and of the best quality. The supply at present is sufficient for all needs, but it is doubtful if it will be ample for the future.

Latah uses wells exclusively as a source of water supply. Later on water may be taken from a large spring above the town. The wells are shallow, as a rule, varying in depth from 25 to 40 feet. They enter rock, and a layer of clay at the surface tends to prevent contamination from above. The water level varies but little throughout the year. One well sunk to a depth of 135 feet flows constantly.

The city of Spokane obtains its supply of water from Spokane River. The pumping plant is on the river bank about 5 miles above the city. A direct pressure system of waterworks is used. There are no sources of contamination and the water is of a high degree of purity, as well as ample in quantity for all probable future needs.

The following sanitary analysis of city water from Spokane was made on April 23, 1901, by Prof. H. G. Byers, of the University of Washington:

Sanitary analysis of city water from Spokane.

[Parts per million.]

Total solids	50.24
Nonvolatile solids	34.43
Volatile solids	15.81
Oxygen consumed	2.13
Chlorine	1.50
Nitrogen as free ammonia	.004
Nitrogen as albuminoid ammonia	.0363
Nitrogen as nitrites	None.
Nitrogen as nitrates	.018

Deep wells.—The Hillyard Town Site Company has a well which is used to supply the town of Hillyard with water. It has a diameter of

44 inches and a depth of 200 feet. It was dug in 1900 at a cost of $500. The amount of water obtained is about 50,000 gallons per day. The water level in the well rises and falls with the water level of Spokane River, which flows not far away.

Springs.—William Forthman owns a spring near Latah, in sec. 26, T. 21 N., R. 45 E. The water issues as a small stream at the foot of a hill. The spring has a minimum flow of 720 gallons per day and is much stronger in the springtime. The water is soft, clear, and of excellent quality. It is used for general farm purposes. In the vicinity of Latah are a number of large springs.

STEVENS COUNTY.

General statement.—Stevens County lies in the northeast corner of the State, bordering on Idaho and British Columbia. The surface is characterized by three conspicuous mountain ridges and three north-south valleys. The ridges lie between Columbia and Colville rivers, between Colville and Pend Oreille rivers, and east of the latter stream along the county boundary. Of the three ridges the first one mentioned is the lowest, with an average height of about 4,500 feet. The second and third ridges have a maximum elevation of about 7,000 feet. Columbia River flows in a deep valley that is usually bordered by glacial terraces. The valley of Colville River is wide and the stream has an extensive flood plain, which overflows at certain seasons of the year. For the first 50 miles of its course within the county Pend Oreille River flows very slowly, in a broad valley that is bordered with much agricultural land; farther down the stream crosses a belt of harder rocks, in which it flows in a long, tortuous canyon.

The rainfall averages about 20 inches per year. This is sufficient to permit of agriculture without irrigation. Practically the entire county was once forested, although the region seems to be near the border land of forest and prairie. The trees do not grow very near together and the undergrowth is very scant. As a rule the grasses grow everywhere among the trees. The forest is being removed at a rapid rate, the demands of the lumbermen on one hand and of the farmers on the other tending toward the deforesting of the county in a comparatively short time.

Stevens County is largely a region of crystalline rocks. The north-south ridges between the principal streams are composed chiefly of granite. Flanking the granites and within the valleys are large areas of marbles, quartzites, slates, and other metamorphic rocks. The marbles occur very generally throughout the county and are of economic importance both as an ornamental stone and for the manufacture of quicklime. At several places are outcrops of coal-bearing sandstones and shales, which represent remnants of lacustrine sediments of

Tertiary time. The basalt of the Columbia River lava extends a little way into the county along the southern boundary. The towns depend for the most part upon streams for their water supplies. The water in virtually every stream is free from contamination and is of excellent quality. In general, the soil is of sufficient thickness to contain enough water for the domestic supplies needed in the smaller towns and through the country. The wells for the most part are shallow and do not often exceed 40 or 50 feet in depth.

Municipal systems.—Bossburg secures water from Columbia River, beside which the town is situated. The water is pumped into a reservoir, from which it is distributed about the town by gravity. The supply is satisfactory in every way. There are no wells about Bossburg, but there are some springs which are utilized.

Colville depends mainly upon springs, but in part upon two streams, for its water supply. The water from all of these is of fine quality, there being no sources of contamination. A gravity system of waterworks has been installed. The wells about Colville range in depth from 10 to 30 feet, the usual depth being 20 feet. The water comes from beds of sand, which are overlain by clay.

Water for Marcus is taken from Columbia River. The water is satisfactory from all standpoints. The wells vary from 18 to 60 feet in depth. Beds of clay are first penetrated, then sand, and finally gravel.

Northport obtains its water supply from Deep Creek, a small stream emptying into Columbia River. There are no sources of contamination, and the water is satisfactory, although very hard. A large amount may be secured, sufficient for all future needs. The water is first pumped into tanks which stand upon a hill above the town and is then distributed by gravity. Besides its domestic use it is also used as a boiler supply by the Northport Smelting and Refining Company.

The water for Springdale is taken from a mountain stream. The spring flows for some distance over limestone, hence the water contains some lime. The supply is believed to be sufficient for all future needs. A gravity system of waterworks is in use. The wells about Springdale range from 30 to 100 feet in depth, water being commonly found at depths of 40 to 50 feet. The more shallow wells are wholly in the soil or mantle rock, but the deeper wells all enter bed rock.

Deep wells.—In sec. 9, T. 35 N., R. 39 E., near Colville, the Pacific States Oil Company drilled a well in 1901 when prospecting for oil. The total depth reached was about 700 feet. At the top the well has a diameter of 10 inches, at the bottom 6 inches. A water-bearing stratum was reached at 400 feet, and water now flows from the well mouth at the rate of 3 or 4 gallons per minute. The cost of the well was $3,000. In drilling the well, beds of limestone, sandstone, limestone, shale, and sandstone were passed through in succession.

THURSTON COUNTY.

General statement.—Thurston County is located in the southwestern portion of the State, at the head of Puget Sound, with Chehalis County lying between it and the Pacific Ocean. The county lies entirely within the basin of Puget Sound and the surface is essentially that of a low plain. For the most part the plain is quite level, with here and there occasional low hills. In the western part of the county the Black Hills rise 300 or 400 feet above the general level. In the southeastern part of the county there are a few low hills which mark the extreme outliers of the Cascades. The Puget Sound shore is very irregular, abounding in indentations and bordered by numerous islands.

In the central part of the county the annual rainfall averages 50 inches. In the eastern and western parts it is 60 inches or a little more. The precipitation is practically altogether in the form of rain, since falls of snow occur very rarely.

The bed rock is not often exposed in Thurston County. In the neighborhood of Tenino and Bucoda there are occasional outcrops of sandstone, which are of economic importance, as they afford a good grade of building stone, and also contain coal, which has been mined to some extent. In the northwestern part of the county, at Gate, there are several outcrops of basalt, but how far north, within the Black Hills, this rock extends is not known. Glacial sediments abound over nearly the entire county. These sediments are usually coarse gravels which represent outwash plains. Oftentimes the gravel plains are soil covered to such a slight degree that they are almost barren. Upon the plains the forest growth when present is very sparse and prairie conditions often prevail. The rainwater sinks away quickly into the gravels and the drainage is largely underground. The streams are few, only the larger ones flowing persistently throughout the year. Occasionally a good soil covers the gravel plains and good farming land is found. The hills noted above are heavily forested, and from them several streams flow out upon the plains. An ample supply of water is easily obtained throughout the county. Within the region of the gravel plains water is often obtained from springs and may always be had by means of wells, which rarely exceed 50 feet in depth. From the beds of sand and gravel in the vicinity of Olympia excellent water has been obtained from wells that vary from 125 to 175 feet in depth, the water sometimes outflowing at the surface.

Municipal systems.—The water supply for Olympia is obtained from springs. The water is pumped into a reservoir, from which it is distributed by a gravity system. At the present time about 3,000,000 gallons per day are obtained. This will doubtless prove sufficient for all future needs.

The Tenino water supply comes entirely from wells, which have an average depth of about 35 feet and are wholly in sand and gravel. The supply of water, while ample for present needs, will doubtless have to be superseded by a larger supply in the future.

Deep wells.—On the capitol grounds in Olympia some wells have recently been drilled in order to secure a water supply for the capitol building. No rock was penetrated in drilling the wells, the water-bearing material being sand. Two of these wells have depths of 152 feet each, and the third has a depth of 138 feet. Each well has a diameter of 2 inches. They are all flowing wells, the water rising about 2 feet above the ground. From the deeper wells flows of 6 and 4 gallons per minute are obtained, while from the third well a flow of 2 gallons per minute is had. The wells are located about one-fourth mile from the shore of Puget Sound and their mouths are 25 or 30 feet above mean tide. The rate of flow diminishes at low tide and increases at high tide. The wells have been cased throughout with 2-inch casing. The cost of drilling the wells was $1 per foot.

WALLAWALLA COUNTY.

General statement.—Wallawalla County is located in the southeastern part of the State, along the Oregon boundary, and east of Columbia and Spokane rivers. The region along Columbia River is very low, being but 300 or 400 feet above the sea. From this low plain there is a gradual ascent eastward in the direction of the Blue Mountains. The eastern part of the county is a region of high, rolling hills, with deep ravines or valleys. The hills in outline show the influence of the wind, and many of them are essentially of eolian origin. The prevailing winds are from the southwest, and hence the hills have their more moderate slopes upon their southwestern sides, while their steeper slopes are to the northeast.

The rainfall shows a very close relationship to elevation. In the lowest part, along Columbia River, the annual rainfall amounts to 10 inches or a little less. In a north-south belt through the center of the county it is 15 inches, and in the eastern part it reaches 20 or 25 inches. This is sufficient to afford a tree growth which, though sparse at first, becomes of considerable importance when the summit of the Blue Mountains is reached. Through the central part of the county trees do not grow naturally, and prairie conditions prevail. At the western end of the county, where the rainfall is least, grasses give way to sagebrush. In this part of the county irrigation is necessary in order that agriculture may be carried on successfully. The rolling prairies of the major portion of the county are famous wheat producers, and in the neighborhood of Walla Walla very fine fruit is raised.

In the northwestern part of the county the rocks are in the main sandstones and shales, which were deposited in a lake in middle Tertiary time. Along the Snake and the Columbia these rocks are largely covered by alluvial deposits. In the remaining part of the county the bed rock, as far as known, is altogether basalt. Usually the rock is deeply buried by the heavy mantle of soil, and outcrops but rarely. Springs often occur along the bases of the hillsides, wherever porous basalt appears at the surface. The wells are usually shallow and dug entirely within the soil. The deep well which has recently been drilled near Walla Walla is of great importance, since it has established the fact that an artesian basin exists here, and that flowing water may be secured at depths of from 500 to 600 feet.

Municipal systems.—The water supply of Walla Walla is secured chiefly from springs, but in part from infiltration ditches. The amount of water is barely sufficient in the dry season, and a larger supply is now being developed at a point about 3 miles above the city.

A sanitary analyses of the Walla Walla city water, made on April 12, 1901, by Prof. H. G. Byers, of the University of Washington, resulted as follows:

Sanitary analysis of city water from Walla Walla.

[Parts per million.]

Total solids	81.67
Nonvolatile solids	62.86
Volatile solids	18.81
Oxygen consumed	2.89
Chlorine	1.50
Nitrogen as free amonia	.008
Nitrogen as albuminoid ammonia	.0267
Nitrogen as nitrites	None.
Nitrogen as nitrates	.452

Waitsburg obtains a water supply from springs in autumn, winter, and spring, and from a creek in summer. The springs afford excellent water, and it is planned to replace the creek water by water from deep wells. A gravity system of waterworks is in use. The wells about Waitsburg vary in depth, the shallow ones being wholly in soil and broken rock, while the deeper ones enter the bed rock. In wells of the first type water is usually found at 15 to 25 feet, while in the second instance the usual depth is 40 feet.

Deep wells.—On the farm of the Blalock Fruit Company, near Walla Walla, a well has recently been drilled (completed May 1, 1903). It has a diameter of 6 inches and a depth of 564 feet. The first rock encountered was basalt, at a depth of 540 feet. The well is a flowing one, the rate of flow being 130 gallons per minute. The temperature of the water at the well mouth is 67° F. The well has been cased to a depth of 540 feet. The water is used in irrigation. The cost of drilling the well was $1,800.

WHATCOM COUNTY.

General statement.—Whatcom County lies in the northwestern part of the State, adjoining British Columbia, and extends from the summit of the Cascades to the Strait of Georgia. Topographically the surface presents two distinct divisions, the plain of the western half and the high mountains of the eastern part. The average height of the plain is 200 or 300 feet above the sea. In the southeastern part of the county are a number of high hills, which give to the plain a broken character. The mountains begin somewhat abruptly, the transition from the plain to the real mountains being quickly made. The highest peak, Mount Baker, stands at the western front of the Cascades, and from this point to the divide on the east the whole area is very rugged. The high mountains have been deeply dissected, and this region is regarded as one of the most difficult to penetrate in the entire Cascades.

The maximum rainfall is 45 inches per year. This occurs in a north-south belt in the vicinity of Mount Baker and also in the northwest corner of the county. From Mount Baker eastward there is a gradual decrease in the rainfall, so that the amount is about 30 inches on the border of the county. Southwest of Mount Baker, also, the rainfall decreases to 35 inches in the vicinity of Bellingham Bay. Mount Baker and all of the highest mountains are covered with snow fields and glaciers. These serve as reservoirs and assure a constant flow to the streams throughout the year. The abundance of precipitation and the great elevations of the region give rise to waterfalls, which will be of great usefulness for power purposes. The falls of the Nooksack, with an effective head of water of 179 feet, are now being developed.

What is now the western part of the county was a large lake in Tertiary (probably Oligocene) time. The deposits made in this lake were mainly sandstones, with some conglomerate and a little shale. These rocks outcrop very commonly in the southeastern part of the county, but in the northwestern portion they are almost entirely covered with glacial sediments. The lacustrine sediments aggregate many thousands of feet in thickness, their extent in this direction being as yet unknown. They are coal bearing near the base. The principal mines for the mining of this coal are located at Blue Canyon, on the shore of Lake Whatcom. The mountainous part of the county is virtually unknown geologically, but the rocks are chiefly metamorphics and igneous intrusions, with great lava flows in the vicinity of Mount Baker.

Whatcom County is abundantly supplied with water. The mountain streams furnish a large amount of excellent water for the use of the towns upon the plains. There are also a number of glacial lakes,

such as Whatcom, Padden, and Samish, which are natural reservoirs of good water. From the glacial sediments of the northwestern part of the county large quantities of water are obtained from springs or by means of wells. The glacial sediments are usually made up of alternating beds of till and water-bearing gravel and sand, and surface contamination is thereby eliminated.

Municipal systems.—The water supply for Blaine comes from springs. The water flows into a reservoir, from which it is distributed by gravity. The quality of water is very good, and the quantity sufficient for all future needs. The wells in use about Blaine are shallow, ordinarily not more than 14 feet in depth. Water is found in gravel, usually at a depth of 10 feet. The town supply is used in the boilers of sawmills, and in the salmon canneries, and for general domestic purposes.

Fairhaven obtains a water supply from Lake Padden, a glacial lake south of the city. A gravity system of waterworks is used. A large amount of water may be obtained from this lake, but if the supply should ever be insufficient water may also be taken from the South Fork of Nooksak River or from Lake Samish. The water from Lake Padden is very pure, as is shown by the following analysis, made by the Deakbof Drug and Chemical Company, of Chicago:

Analysis of water from Lake Padden.

[Grains per gallon.]

Silica	0.467
Calcium sulphate	.329
Magnesium carbonate	.129
Sodium and potassium sulphates	.606
Sodium and potassium chlorides	.401
Iron oxide	None.
Total solids	1.932

In Sumas wells are depended upon, primarily, as a source of water supply, although some small streams are used to a slight degree. Water obtained in this way is of good quality, although the quantity is hardly sufficient for present needs, and some other source must be provided in the future. It has been suggested that a deep well be bored as a future source of supply. Wells in and about the town of Sumas are driven wells, for the most part, and have a range in depth of 40 to 90 feet. Water is most commonly found between 40 and 60 feet. The glacial sediments about Sumas are thick, and the wells have been driven entirely in these. Beds of clay were usually encountered first, with beds of sand and gravel below, from which the water was obtained. In a few instances the water in the wells rises to the surface. The water level varies but very little from season to season.

The city of Whatcom obtains its water supply from Lake Whatcom. The lake is several square miles in area and is located in the hills southwest of the city. It lies at a sufficient height above the level of the town to give a good head to the water, so that a gravity system of waterworks may be used. The water is of excellent quality, the only sources of contamination being sawdust and other refuse from the sawmills on the shores of the lake. The catchment basin of the lake is of ample size and insures a large storage of water in the lake basin, so that the water supply will be sufficient for all the future needs of the city. The water is used for domestic purposes and in the many manufacturing plants which are located about Whatcom. The following sanitary analysis of water from Lake Whatcom was made March 16, 1901, by Prof. H. G. Byers, of the University of Washington:

Analysis of water of Lake Whatcom.

[Parts per million.]

Total solids	158.86
Nonvolatile soiids	116.52
Volatile solids	42.34
Oxygen consumed	2.03
Chlorine	3.80
Nitrogen as free ammonia	.004
Nitrogen as albuminoid ammonia	.033
Nitrogen as nitrites	None.
Nitrogen as nitrates	None.

WHITMAN COUNTY.

General statement.—Whitman County lies along the Idaho boundary, south of Spokane County and east of Adams County. The surface is in general that of a plateau, with an average height of about 2,000 feet above the sea. Rising above the plateau, especially along the eastern border of the county, are several high hills which represent the extreme outliers of the mountains of Idaho. Of such hills Steptoe Butte is a good example, rising about 700 feet above the plateau. The plateau is generally covered with low hills of a marked eolian type. From the profiles of these hills it is seen that the prevailing winds which fashioned them came from the southwest. Along the southern border of the county Snake River flows in a canyon which has a depth of from 2,000 to 3,000 feet below the level of the plateau. The principal tributaries of the Snake within the county likewise flow in canyons, and hence indicate that the dissection of the plateau is under way.

The average rainfall is about 20 inches. This decreases to 15 inches along the western border and increases to 25 inches in the higher portion along the eastern boundary. With the exception of a slight forest growth on the eastern margin and of a few trees which grow in the valleys along the streams, the entire county was once clothed with

grasses. The rainfall is of sufficient amount to make the growth of wheat possible, so that wheat fields now cover almost every part of the plateau. Irrigation is employed only in the canyons of the larger streams, such as the Snake. Upon the terraces or benches that border the latter river large fruit ranches are found, the water for irrigation being supplied by the small tributary streams.

In the plateau above mentioned basalt forms the bed rock almost exclusively. The few buttes or hills along the eastern boundary, which project above the plateau, are composed of granites, gneisses, schists, quartzites, and similar rocks, which indicate the character of the floor upon which the basalt outflowed. Along the canyon of Snake River in two or three places granite appears, showing that the river in trenching the basalt is bringing to light the rocks beneath it. The walls of the canyon of Snake River show the basalt in a series of 8 or 10 practically horizontal flows. The plateau is covered with a deep soil and the underlying rock rarely appears. Because of its eolian nature the soil is of a very fine grain and has the property of retaining moisture to a very marked degree. Oftentimes wells dug only into the soil afford a good supply of water. The towns usually depend upon deeper wells drilled into the basalt for their water supplies. As a general thing these wells range in depth from 100 to 300 feet. In some instances, as at Pullman, water is obtained from beds of sand and gravel between the layers of basalt. In other cases very porous layers of basalt often afford a plentiful supply of water. In some cases flowing wells are secured, this being especially true when the wells are drilled in the bottoms of the canyons or in deep valleys. Springs are very common along the valley sides wherever porous basalt appears at the surface.

Municipal systems.—Colfax obtains its city supply from Palouse River. In this way very good water is obtained; but it is possible that in the future deep wells may be substituted as a source of supply. The water is pumped into a reservoir located on a hill above the city, from which it is distributed by gravity. The wells about Colfax range from 12 to 120 feet in depth. Water is usually found at a depth of about 40 feet. All the deeper wells enter the rock, which is basalt. No flowing wells have been found; in every instance the water must be pumped.

Oakesdale depends chiefly upon wells, although a few springs and cisterns are used. At some places the water is soft, but at other places it is hard. Generally speaking, there are no sources of contamination and the water is quite satisfactory. The wells on the hills about Oakesdale have been sunk to depths of from 45 to 60 feet in order to obtain water. On the plain at the foot of the hills they are shallow, ranging from 10 to 15 feet in depth. In the shallow wells a clay hardpan with sand and gravel below are the only materials penetrated, while all the

deeper wells enter the basaltic rock. The supply of water in the wells is stationary, neither increasing nor decreasing as far as known.

Pullman obtains a water supply from artesian wells. The wells vary in depth from 100 to 130 feet, water being most commonly found at 100 feet. The wells are in basaltic rock, the water coming from beds of sand interstratified with the layers of basalt. About 150,000 gallons of water are obtained daily. The capacity of the wells, however, is such that this supply could be doubled if it were necessary. It is noted that the wells do not flow as strongly as they did when they were first drilled. A gravity system of waterworks is used, the water being first lifted by steam pumps from the wells to a reservoir. An analysis of the city water, made by Prof. Elton Fulmer, of the Washington Agricultural College and School of Science, shows the following composition:

Analysis of city water from Pullman.

[Grains per gallon.]

Silica (SiO_2)	3.49
Potash (K_2O)	.50
Soda (Na_2O)	1.75
Lime (CaO)	1.86
Magnesia (MgO)	1.31
Iron oxide (Fe_2O_3)	.06
Alumina (Al_2O_3)	.03
Sulphuric acid (SO_2)	.08
Carbonic acid (CO_2)	3.73
Chlorine	.15
Total solids	12.96

Tekoa depends entirely upon an artesian well for its water supply. From this well water of a good quality is obtained, there being no contamination as far as known. The supply is at present sufficient, but will not be large enough in the future. In the region about Tekoa water is most commonly found at a depth of about 100 feet, although some of the wells reach depths of 175 feet. All of the wells enter rock. In most instances the water rises to the surface, and in some cases reaches a height of 10 feet above the mouth of the well.

Uniontown obtains its water supply from a deep well. The water is soft and very satisfactory in every way, and the quantity is ample for present needs at least. The deepest wells about Uniontown have a depth of about 200 feet. These wells enter the rock and obtain water from beds of sand and gravel intercalated with basalt. There are some surface wells which do not enter the rock and which are from 7 to 10 feet in depth. In none of the wells does the water rise to the surface. The water level does not vary during the day or year and is not affected by pumping.

Deep wells.—About Palouse a number of wells have been drilled. In general they have a diameter of 6 inches and a depth of from 100

to 300 feet. The depth to the principal source of water is, on the average, 150 feet. The water is found in beds of sand which lie below a capping of basalt. From some of the wells the water flows, while in others the water level stands below the surface and pumping must be resorted to. The level does not vary during the day or year, the supply being constant from season to season. The water as a rule is hard, generally containing magnesia and iron. The usual temperature of the water at the well mouth is 50° F. The wells are mostly owned by farmers, and the water is used for general farm supply. The average cost of a well is $300, while the pumping machinery costs from $100 to $200. As a rule the wells are only partially cased, the length of casing varying from 20 to 120 feet.

In and about the city of Pullman are a number of artesian wells, of which the two owned by the city and used as a source of municipal water supply may be taken as types. One of these wells was drilled in 1890 and the other in 1899. They are located near the bed of a stream which flows through the center of the city. The mouths of the wells are at an elevation of 2,341 feet above the sea. Each well has a depth of 110 feet, with a diameter of 6 inches. The wells flow and the water rises to a height of 19 feet above the surface. The temperature of the water at the well mouth is about 60° F. The supply of water has decreased since the wells were drilled. Both wells are cased throughout with 6-inch heavy wrought-iron pipe. The cost of each well was about $450, and the cost of the pumping machinery necessary to lift the water to the reservoir was about $3,000.

In Tekoa there is an artesian well that was drilled in 1892 to serve as a source of water supply for the town. The well was drilled on a stream bed. It has a depth of 176 feet and a diameter of 6 inches. Only one water-bearing bed was found, that at the bottom of the well. The water rises to a height of 8 feet above the surface, and has a temperature of 76° F. at the well mouth. The water level has shown no seasonal variation, and the supply has been constant. The cost of the well was $750, and the cost of the pumping machinery was $1,000. The casing has been placed in the well only from the surface to solid rock. The Oregon Railroad and Navigation Company owns a deep well at this place, from which is obtained a water supply for locomotives.

YAKIMA COUNTY.

General statement.—Yakima County is located in the south-central part of Washington, between Columbia River and the summit of the Cascade Mountains. The surface presents a great diversity topographically. Columbia and Yakima rivers are bordered by broad, low plains. Between these streams are a number of ridges or low mountains which rise a few hundred feet above the general level of the

plain. Southwest and west of Yakima River the plain merges into an even-topped plateau, which in the course of 20 or 30 miles gives way to the foothills of the Cascades. The mountains are comparatively low, with a general height of 4,000 to 5,000 feet, except in the vicinity of Mount Adams, in the southwestern part of the county, where they are much higher, reaching a maximum of 12,400 feet.

As the county lies partly within the Cascade Mountains and partly within the Columbia Plains, it has geologic features common to both provinces. The formations of those portions of the Cascades within the county are scarcely known at all, but are believed to consist mainly of metamorphic and igneous rocks typical of the interior of the range. Immediately east of Cowlitz Pass are limited areas of Tertiary shales and sandstones which contain seams of coal. The coal is a semi-anthracite, or a true anthracite in some cases. Along the eastern flank of the mountains are occasional flows of andesite, most of which are of a very late date.

The eastern part of the county lies within the Columbia Plains, and here the rocks belong almost wholly to two divisions, viz, the Yakima basalt and the Ellensburg formation. The Yakima basalt, according to Smith, has a vertical thickness in the canyon of Yakima River of more than 2,500 feet, and represents ten or more separate flows. For the most part the basalt is compact and heavy, but occasionally it is cellular or scoriaceous. In color it is black, except on weathered surfaces, where it usually has become brown. In a few instances the so-called ash beds, consisting of fine and coarse tuffs, are found interbedded with the dense compact basalt. The latter has usually a prismatic or columnar structure, the result of the contraction or shrinkage of the lava in the process of cooling. The Ellensburg formation lies directly on the Yakima basalt, and includes shales, sandstones, and conglomerates that, in the main, were deposited immediately after the last flows of lava. In some places there was a final outflow of lava a little while after the beginning of the deposition of the clastic rocks. The sediments of the Ellensburg formation accumulated to a thickness of 1,500 feet or more, and on the evidence of fossil leaves are known to be of Miocene age. These rocks are but partially consolidated, and have suffered considerable erosion, with the result that they have been wholly or in large part removed from much of the area that they once covered. This formation is of special interest. It contains water, and within it the artesian wells of the county have been drilled.

The Yakima basalt and the Ellensburg formation have been folded into a series of arches and troughs, or anticlines and synclines, that have, in general, an east-west direction. The general structure of the region is well shown along the course of Yakima River, which has cut directly or obliquely across the ridges and alternating troughs. As a rule the arches or ridges are comparatively long and narrow, and

rise from 800 to 1,500 feet above the intervening valleys. The arches are almost invariably capped by basalt, the rocks of the Ellensburg formation being limited to the valleys and the lower flanks of the ridges.

The rainfall of Yakima County shows as great a variation in amount as is to be found in any area of similar size within the State. In the eastern portion the annual rainfall averages 10 inches or a little less. From the vicinity of North Yakima westward it increases regularly toward the summit of the mountains. Upon the plateau it ranges from 15 to 25 inches. In the mountains it varies from 30 inches in the foothills to a maximum of 50 inches along the summit. The effect of the rainfall upon the vegetation is of interest. The western end of the county is so well forested that it is included within the Mount Rainier Forest Reserve. The plateaus and hills of the central and eastern parts are bare of trees, but are abundantly covered with grasses. Along the low plains of Yakima and Columbia rivers the grasses largely disappear and sagebrush takes their place as the principal vegetal covering. Except for the growing of wheat upon the plateaus, no attempt is made to carry on agriculture without recourse to irrigation. The water for irrigation is obtained chiefly from the streams, but to some extent from artesian wells. The streams coming from the mountains, where the rainfall is heavy, carry a large amount of water. Even without the use of impounding reservoirs, enough water may be had to irrigate a large part of the plains. In the vicinity of North Yakima a number of deep wells have been drilled, which furnish sufficient water to irrigate large tracts of land. The character and extent of this artesian basin have been set forth in Water-Supply and Irrigation Paper of the United States Geological Survey, No. 55. The towns, as a rule, depend upon streams for their supply of water, although surface wells are frequently used. Upon the plateaus and about the foothills springs are often found, some of which might be classed as mineral springs.

Municipal systems.— North Yakima obtains its supply of water from Naches River. The quantity obtained is sufficient for the present and probably for all future needs. The Naches rises in the foothills of the Cascades, and as there are no sources of contamination the quality of water is good. A few wells are used about North Yakima. They range in depth from 18 to 25 feet and are wholly in sand and gravel. The city water supply is used to a very large degree for irrigating, besides serving as a domestic supply.

A sanitary analysis of water from the North Yakima city supply, made on April 8, 1901, by Prof. H. G. Byers, of the University of Washington, resulted as follows:

Sanitary analysis of city water at North Yakima.

[Parts per million.]

Total solids	169.53
Nonvolatile solids	114.85
Volatile solids	54.68
Oxygen consumed	1.79
Chlorine	2.75
Nitrogen as free ammonia	.008
Nitrogen as albuminoid ammonia	.0177
Nitrogen as nitrites	None.
Nitrogen as nitrates	None.

The town of Prosser obtains a water supply from Yakima River. The river gets very low in autumn and may not afford sufficient water to meet the future needs of the town. The water is pumped into a reservoir and is distributed by a gravity system. A few wells have been dug in the region, and these have a depth ordinarily of about 40 feet. They do not enter bed rock, but are wholly in gravel.

Deep wells.—In sec. 4, T. 20 N., R. 12 E., is a deep well owned by F. E. Deeringhoff. It is located on a gentle slope at an elevation of about 1,100 feet above the sea. It was completed in April, 1899. The well was drilled to a depth of 275 feet and then bored for the remainder of the way, a distance of 350 feet. The drilled portion has a diameter of $5\frac{5}{8}$ inches, while the bored part has a diameter of 3 inches. Three water-bearing beds were found, the first at a depth of 200 feet, the second at 400 feet, and the third and principal one at 625 feet. The principal water-bearing material is sand. When the well was completed the water rose to a height of 40 feet above the surface, but at present it rises to a height of but 1 foot above the well mouth. The temperature of the water at the surface is 74° F. The water is soft and is sulphur bearing to a slight degree. In casing the well 40 feet of 5-inch, 120 feet of 4-inch, and 80 feet of 3-inch pipe were used. The water is used entirely for irrigation.

In sec. 8, T. 12 N., R. 20 E., J. H. Gano has an artesian well located on a plain. The well was drilled, and has a depth of 826 feet. In the upper portion the diameter is 4 inches, while in the lower portion it is only $2\frac{1}{2}$ inches. Water-bearing beds were found at depths of 300 and 400 feet, besides the principal bed at the bottom. The temperature of the water at the well mouth is 78° F. The water rises 40 feet above the surface. The supply has not decreased since the well was completed. The cost of the well was $1,000. The water is used for irrigating purposes.

In sec. 9, T. 12 N., R. 20 E., E. S. Hill has a deep well, which was completed in 1900. The well was drilled on the slope of a hill, and has a depth of 626 feet. From 200 feet downward several water-bearing beds were found, the principal one being a stratum of sand at the bottom. The well flows, and the supply has not increased or

decreased since the well was completed. The temperature of the water at the well mouth is 74° F. The cost was $900. In the well 490 feet of casing has been placed, the upper portion of this having a diameter of 4½ inches and the lower portion a diameter of 3½ inches. The water is used exclusively for irrigation.

In sec. 6, T. 12 N., R. 20 E., is an artesian well owned by J. W. Peck. The well is located in a valley, at a height of about 800 feet above sea. It was completed in 1901 at a cost of $1,200. It has a diameter of 6 inches and a depth of 828 feet. The principal flow of water was found in a sandstone, but other minor water-bearing beds were encountered in drilling. The well is a flowing one, the water rising 4 feet above the surface. The water flows a little less strongly in the summer than in the winter, but on the whole the amount of water remains fairly constant. The temperature of the water at the well mouth is 74° F. The water carries a little iron, magnesia, and sulphur.

In sec. 10, T. 12 N., R. 20 E., Robert Rein has a deep well, which was completed in 1900. The depth of the well is 570 feet, the diameter at the top is 6¼ inches and at the bottom 2¾ inches. The well is located on a plain at a height of 1,500 feet above the sea. The water rises about 20 feet above the surface, and the supply has been constant since the completion of the well. The temperature of the water at the well mouth is 60° F. The cost of the well was $700. The water is used for irrigating purposes.

In sec. 8, T. 12 N., R. 20 E., is an artesian well owned by Julius Sauve. It is located on a plain at an elevation of 1,155 feet above sea. The diameter of the well in the first portion is 4¾ inches and in the bottom portion 2 inches. A number of different flows of water were encountered at depths of 790, 861, 876, 890, 907, and finally at the bottom at 1,020 feet. The water rises 80 feet above the surface. The quantity of water has not changed since the well was first drilled. The water at the well mouth has a temperature of 75.2° F. The cost of the well was $1 per foot, or $1,020.

In sec. 8, T. 12 N., R. 20 E., David Walters drilled a well which was completed July 12, 1902. It has a depth of 1,200 feet and a diameter of 5¼ inches. The well is a flowing one. The temperature of the water at the well mouth is 81° F. The cost of the well was $1,600. In casing the well 400 feet of pipe with a diameter of 4 inches and 620 feet of pipe with a diameter of 3¼ inches were used.

Springs.—In T. 9 N., R. 12 E., on Government land, spring water issues as a stream from the base of a bluff of basaltic rock. The water is very cold, free from any odor, and colorless. From the water bubbles of gas are constantly escaping. An analysis of the water made by Prof. H. G. Byers, of the University of Washington, resulted as follows:

Analysis of water from spring in T. 9 N., R. 12 E.

[Parts per million.]

Volatile solids	363.5
Nonvolatile solids	774.5
Total solids	1,138.0
Silica	109.3
Ferric oxide and alumina	82.0
Calcium carbonate	266.4
Magnesium carbonate	177.7
Sodium chloride	213.4
Potassium chloride	38.7
Calcium sulphate	None.
Potassium sulphate	None.

In sec. 9, T. 11 N., R. 15 E., on tribal land belonging to the Yakima Indians, are some warm and cold springs. The water issues as small streams from soil and gravel. About the springs are deposits of reddish matter, presumably iron oxide. The cold springs have a soda taste, and from them all bubbles of gas are constantly escaping. The warm springs are used by the Indians for bathing, and the water is believed by them to possess medicinal value. It is used more for rheumatism than for any other disease. From all of the springs the quantity of flow is constant, no variation being appreciable from season to season.

TABLES OF DEEP WELLS, MUNICIPAL WATER SUPPLIES, AND REPRESENTATIVE SPRINGS.

Deep wells in Washington.

County and post-office.	T.	R.	S.	Name of owner.	Topographic position.	Elevation above sea.
Adams County:						*Feet.*
Cunningham	16	30	22	Thomas and James O'Hair.	Hill	1,278
Ritzville	16	32	33	Northern Pacific Rwy.	Valley	1,157
Franklin County:						
Connell	13	32	28	W. T. Braden	Valley	840
Island County:						
Coupeville	....	....	....	E. J. Hancock	Hill	125
Spokane County:						
Hillyard	....	....	....	Hillyard Town Site Co	Plain	2,000
Stevens County:						
Colville	35	39	9	L. J. Walford	Base of hill	1,590
Thurston County:						
Olympia	....	....	....	State of Washington	Plain	30

Deep wells in Washington—Continued.

County and post-office.	T.	R.	S.	Name of owner.	Topographic position.	Elevation above sea.
						Feet.
Wallawalla County:						
Walla Walla	7	35	27	Blalock Fruit Co	Plain	825
Whitman County:						
Palouse	....	....	....	F. P. Egan	Valley	2,000
Pullman	14	45	5	City of Pullman	Stream bed	2,341
Tekoa	....	....	....	Town of Tekoa	....do	.....
Yakima County:						
North Yakima	20	12	4	F. E. Deeringhoff	Slope	1,100
Do	12	20	8	James H. Gano	Plain	1,100
Do	12	20	9	E. S. Hill	Slope	.....
Do	12	20	6	J. W. Peck	Valley	800
Do	12	20	10	Robert Rein	....do	1,500
Do	12	20	8	J. Saure	Plain	1,155
Do	12	20	8	David Walters	Slope	.....

County and post-office.	Date when completed.	Kind of well.	Diameter.	Depth.	Depth to principal source of water.	Water-bearing material.
			Inches.	*Feet.*	*Feet.*	
Adams County:						
Cunningham	1902	Drilled	6	426	426	Rock.
Ritzville	1901	....do	8	355	300	Very porous rock.
Franklin County:						
Connell	1902	....do	5	676	660	Porous rock.
Island County:						
Coupeville	1889	Dug	48	125	120	Sand.
Spokane County:						
Hillyard	1900	....do	44	200	192	Gravel.
Stevens County:						
Colville	1901	Drilled	10 6	700	400	Sandstone.
Thurston County:						
Olympia	1903	....do	2	152	152	Sand.
Wallawalla County:						
Walla Walla	1903	....do	6	564	540	Do.
Whitman County:						
Palouse	.....	....do	6	200	150	Do.
Pullman	1890	....do	6	110	110	Do.
Tekoa	1892	....do	6	176	176	Porous rock.
Yakima County:						
North Yakima	1899	Drilled and bored.	$5\frac{5}{8}$ 3	625	625	Sand.
Do	.....	Drilled	4 $2\frac{1}{2}$	826	820	Do.
Do	1900	....do	.....	626	620	Do.
Do	1901	....do	6	828	828	Do.
Do	1900	....do	$6\frac{1}{4}$ $2\frac{3}{4}$	570	570	Do.
Do	1900	....do	$4\frac{3}{4}$	1,020	1,020	Do.
Do	1902	....do	$3\frac{1}{4}$	1,200	1,200	Do.

Deep wells in Washington—Continued.

County and post-office.	Other water-bearing beds found.	Distance water rises above surface.	Distance of water from surface.	Temperature of water at well mouth.	Amount of water obtained daily.	Increase or decrease of supply.
		Feet.	*Feet.*	° *F.*	*Gallons.*	
Adams County:						
Cunningham	None		356			Increase.
Ritzville	None		235			Stationary.
Franklin County:						
Connell	None		640	51		Stationary.
Island County:						
Coupeville	Yes		120			Do.
Spokane County:						
Hillyard	None		185		50,000	
Stevens County:						
Colville	Yes					
Thurston County:						
Olympia	Yes	2			8,640	Increasing.
Wallawalla County:						
Walla Walla				67	187,000	Stationary.
Whitman County:						
Palouse	None	Several.		50		Do.
Pullman	None	19		60	180,000	Decreasing.
Tekoa	None	8		76		Stationary.
Yakima County:						
North Yakima	Two	1		74		Decreasing.
Do	Two	40		78		Stationary.
Do	Two	Several.		74		Do.
Do	Yes	4		74		Do.
Do	Yes	20		60		Do.
Do	Yes	80		75		Do.
Do		Several.		81		

County and post-office.	Variation in water level.	Effect of pumping on level of water.	Quality of water.	How water is obtained at surface.
Adams County:				
Cunningham	None	None	Soft	Pumping.
Ritzville	do	Lowers level 10 feet.	do	Do.
Franklin County:				
Connell	do	None	do	Do.
Island County:				
Coupeville		Lowers it slightly.	Hard	Do.
Spokane County:				
Hillyard	Varies during year	Lowers level slightly.	Soft	Do.
Stevens County:				
Colville	None		Iron bearing	
Thurston County:				
Olympia	Varies with tide			Well flows.
Wallawalla County:				
Walla Walla	None			Do.
Whitman County:				
Palouse	do	Lowers level	Hard	Do.
Pullman	do		do	Do.
Tekoa	do	None	Soft	Do.

Deep wells in Washington—Continued.

County and post-office.	Variation in water level.	Effect of pumping on level of water.	Quality of water.	How water is obtained at surface.
Yakima County:				
North Yakima	Varies during year		Sulphur bearing.	Well flows.
Do	None		Soft	Do.
Do	do	None	do	Do.
Do	Varies during year		do	Do.
Do	None	None	do	Do.
Do	Varies during year		do	Do.
Do			Sulphur bearing.	Do.

County and post-office.	Cost.	Cost of pumping machinery.	Size and length of casing.	Use made of the water.
Adams County:				
Cunningham	$1,066	$290	Diameter, 2 inches; length, 423 feet.	Farm supply.
Ritzville	2,500		Length, 240 feet	Locomotives.
Franklin County:				
Connell	3,000		Diameter, 5 inches; length, 100 feet.	Farm supply.
Island County:				
Coupeville	350	150		Do.
Spokane County:				
Hillyard	500	2,500		Town supply.
Stevens County:				
Colville	3,000		Diameter, 10 inches; length, 40 feet.	None.
Thurston County:				
Olympia	152		Diameter, 2 inches; length, 152 feet.	Supply for capitol building.
Wallawalla County:				
Walla Walla	1,800		Length, 540 feet	Irrigation.
Whitman County:				
Palouse	300		Diameter, 5⅝ inches; length, 150 feet.	Farm supply.
Pullman	450	3,000	Diameter, 6 inches; length, 110 feet.	City water supply.
Tekoa	750	1,000	Diameter, 6 inches	Town supply.
Yakima County:				
North Yakima			Diameter, 5 inches; length, 40 inches. Diameter, 4 inches; length, 120 inches. Diameter, 3 inches; length, 80 inches.	Irrigation.
Do	1,000		Diameter, 4, 3, and 2½ inches.	Do.
Do	900		Diameter, 4½ inches; length, 497 feet.	Do.
Do	1,200			Do.
Do	700			Do.
Do	1,020			Do.
Do	1,600		Diameter, 4 inches; length, 400 feet. Diameter, 3¼ inches; length, 620 feet.	Do.

Municipal water supplies in Washington.

Location.	Water-supply system.	Principal source of water.	Other sources.	Sufficient supply for present needs.	Sufficient supply for future needs.
Adams County:					
Ritzville	Yes	Deep wells	None	No	No.
Asotin County:					
Asotin	No	Asotin Creek	Wells and cisterns	Yes	Yes.
Clarkston	Yes	do	None	Yes	Yes.
Chehalis County:					
Aberdeen	Yes	Creek		No	No.
Cosmopolis	Yes	Wells	Creek	Yes	Yes.
Hoquiam	Yes	Hoquiam River	None	Yes	Yes.
Montesano	Yes	Springs	do	Yes	Yes.
Oceosta	No	Wells	Springs		
Chelan County:					
Chelan	Yes	Springs	Lake Chelan	No	No.
Lakeside	No	Lake Chelan	Wells	Yes	Yes.
Wenatchee	Yes	Creek	None	Yes	No.
Clallam County:					
Port Angeles	Yes	Frazer Creek	Wells and springs	No	No.
Port Crescent	No	Wells	Pond	Yes	No.
Clarke County:					
Vancouver	Yes	Springs and deep wells.		Yes	Yes.
Columbia County:					
Dayton	Yes	Springs	None	Yes	Yes.
Cowlitz County:					
Castlerock	Yes	Creek	Wells	Yes	No
Kalama	Yes	Creeks	None	Yes	No.
Douglas County:					
Wilsoncreek	No	Wells	Streams	No	No.
Jefferson County:					
Port Ludlow	Yes	Creek	None	Yes	Yes.
Port Townsend	Yes	Deep wells	Wells and cisterns.	No	No.
King County:					
Auburn	No	Wells	White River	Yes	Yes.
Ballard	Yes	Springs and deep wells.		Yes	No.
Columbia City	Yes	Cedar River	None	Yes	Yes.
Enumclaw	Yes	Mountain streams	Wells	Yes	Yes.
Issaquah	Yes	Springs	do	Yes	Yes.
Kent	Yes	do	None	Yes	No.
Renton	Yes	Spring	Wells	Yes	No.
Seattle	Yes	Cedar River and Cedar Lake.	None	Yes	Yes.
West Seattle	Yes	Springs	do	No	No.
Kitsap County:					
Bremerton	Yes	do	Wells	Yes	Yes.
Charleston	Yes	Springs and creeks	do	Yes	Yes.
Port Blakeley	Yes	Creek		Yes	Yes.
Port Gamble	Yes	Creeks		Yes	Yes.
Kittitas County:					
Clealum	Yes	Springs	Wells	Yes	Yes.
Ellensburg	Yes	Mountain streams	do	No	No.
Roslyn	Yes	Springs and Clealum River.		Yes	No.

Municipal water supplies in Washington—Continued.

Location.	Water-supply system.	Principal source of water.	Other sources.	Sufficient supply for present needs.	Sufficient supply for future needs.
Klickitat County:					
Goldendale	Yes	Spring	None	Yes	No.
Lewis County:					
Centralia	Yes	Wells	Skookum Chuck River.	No	No.
Pe Ell	No	do	Springs	No	No.
Lincoln County:					
Davenport	Yes	Springs	None	Yes	No.
Harrington	Yes	Wells	Springs	Yes	No.
Sprague	Yes	Springs	Wells	Yes	Yes.
Wilbur	Yes	Creek and wells	Springs	Yes	Yes.
Mason County:					
Shelton	Yes	Spring	None	Yes	No.
Okanogan County:					
Loomis	Yes	Sinlahekin Creek	Spring	Yes	Yes.
Pacific County:					
Ilwaco	Yes	Spring		Yes	No.
Southbend	Yes	do	None	Yes	Yes.
Pierce County:					
Buckley	Yes	Well	White River	Yes	Yes.
Carbonado	Yes	Springs	None	Yes	Yes.
Orting	Yes	do	Wells	Yes	No.
Puyallup	Yes	do	None	Yes	Yes.
South Tacoma	Yes	Wells	do	Yes	Yes.
Sumner	Yes	Springs	do	Yes	Yes.
Tacoma	Yes	Clover Creek and springs.	Three wells	No	No.
San Juan County:					
Friday Harbor	No	Wells		Yes	No.
Skagit County:					
Anacortes	Yes	Lake Heart	None	Yes	No.
Hamilton	No	Wells	do	Yes	Yes.
La Conner	Yes	Spring		Yes	
Mount Vernon	Yes	do	None	Yes	Yes.
Snohomish County:					
Arlington	No	Springs and wells	Stilaguamish River	Yes	Yes.
Edmonds	Yes	Springs	Wells	Yes	
Everett	Yes	Wood's Creek		Yes	Yes.
Marysville	No	Wells	None		
Monroe	Yes	Creeks	Wells	Yes	Yes.
Monte Cristo	Yes	Mountain stream	None	Yes	Yes.
Silverton	Yes	do	do	Yes	Yes.
Snohomish	Yes	Pilchuck River	do	Yes	Yes.
Spokane County:					
Cheney	Yes	Lake and wells		Yes	Yes.
Hillyard	Yes	Deep wells	None	Yes	No.
Latah	No	Wells			
Medical Lake	Yes	Clear Lake	Wells	Yes	Yes.
Stevens County:					
Bossburg	Yes	Columbia River	None	Yes	Yes.
Colville	Yes	Spring	Creeks and wells	Yes	No.
Marcus	No	Columbia River	None		
Northport	Yes	Deep Creek		Yes	Yes.
Springdale	Yes	Creek	Wells	Yes	Yes.

Municipal water supplies in Washington—Continued.

Location.	Water-supply system.	Principal source of water.	Other sources.	Sufficient supply for present needs.	Sufficient supply for future needs.
Thurston County:					
Olympia	Yes	Springs	None	Yes	Yes.
Tenino	No	Wells	Spring	Yes	No.
Wallawalla County:					
Waitsburg	Yes	Springs	Creeks	Yes	No.
Walla Walla	Yes	do	Creek	Yes	No.
Whateom County:					
Blaine	Yes	do		Yes	Yes.
Fairhaven	Yes	Lake Padden	Three creeks	Yes	Yes.
Sumas	No	Wells	Streams	No	No.
Whatcom	Yes	Lake Whateom	None	Yes	Yes.
Whitman County:					
Colfax	Yes	Palouse River	do	Yes	Yes.
Oakesdale	No	Wells	Springs		
Pullman	Yes	Artesian wells		Yes	Yes.
Tekoa	Yes	do	None	Yes	No.
Uniontown	Yes	Deep well		Yes	Yes.
Yakima County:					
North Yakima	Yes	Naches River	None	Yes	Yes.
Prosser	Yes	Yakima River	do	No	No.

Location.	Quality of water.	Effect of water on the health.	Sources of contamination.	Other sources of supply in contemplation.
Adams County:				
Ritzville	Hard	Good	None	Additional wells.
Asotin County:				
Asotin	Soft	do	do	None.
Clarkston	do	do	do	Artesian wells.
Chehalis County:				
Aberdeen	do	do		Other creeks.
Cosmopolis	do	do	None	None.
Hoquiam	do	do	do	Do.
Montesano	do	do	do	Do.
Oeosta	do	do		Do.
Chelan County:				
Chelan	Hard		Surface drainage.	Lake Chelan.
Lakeside	Soft	Good	None	None.
Wenatchee	Contains iron	do	Surface drainage.	Do.
Clallam County:				
Port Angeles	Soft	Some ill effects in summer.	Decaying vegetation.	Little River.
Port Crescent	Somewhat salty		None	None.
Clarke County:				
Vancouver	Soft	Good	do	Do.
Columbia County:				
Dayton	do	do	do	Do.
Cowlitz County:				
Castlerock	do	do	do	Do.
Kalama	Hard	do	do	Do.

Municipal water supplies in Washington—Continued.

Location.	Quality of water.	Effect of water on the health.	Sources of contamination.	Other sources of supply in contemplation.
Douglas County:				
Wilsoncreek	Alkaline	Good	None	None.
Jefferson County:				
Port Ludlow	Soft	do		
Port Townsend	do	do	None	Mountain streams.
King County:				
Auburn	do	do		White River.
Ballard	do	do		Seattle water system.
Columbia City	do	do		None.
Enumclaw	do	do	None	Springs.
Issaquah	do	do	do	None.
Kent	do	do	do	Additional springs.
Renton	do	do	do	Cedar River and other springs.
Seattle	do	do	do	None.
West Seattle	do	do	do	Cedar River.
Kitsap County:				
Bremerton	do	do	do	None.
Charleston	do	do	do	Do.
Port Blakeley	do	do	Decaying vegetation.	Do.
Port Gamble	do	do	None	Do.
Kittitas County:				
Clealum	do	do	do	Yakima River.
Ellensburg	Hard	do	do	None.
Roslyn	Soft	do	do	Do.
Klickitat County:				
Goldendale	do	do	do	Additiona spring.
Lewis County:				
Centralia	do			None.
Pe Ell	do	Some ill effects.	Sewage	Do.
Lincoln County:				
Davenport	do	Good	None	Do.
Harrington	do	do		
Sprague	do	do	None	Do.
Wilbur	do	do	do	Do.
Mason County:				
Shelton	do	do	do	Other springs.
Okanogan County:				
Loomis	do	do	do	Other creeks.
Pacific County:				
Ilwaco	do	Not good	Decaying vegetation.	None.
Southbend	do	Good	None	
Pierce County:				
Buckley	do	do	do	Do.
Carbonado	do	do	Decaying vegetation.	Do.
Orting	do	do	None	Additional springs.
Puyallup	do	do	do	None.
South Tacoma	Hard	do	do	Do.
Sumner	Soft	do	do	Do.
Tacoma	do	do	do	Additional wells.

Municipal water supplies in Washington—Continued.

Location.	Quality of water.	Effect of water on the health.	Sources of contamination.	Other sources of supply in contemplation.
San Juan County:				
Friday Harbor	Soft	Good	None	
Skagit County:				
Anacortes	do	do	do	Other lakes.
Hamilton	do	do	do	None.
Laconner		do		
Mount Vernon	Soft	do	None	Do.
Snohomish County:				
Arlington	do	do	do	
Edmonds	do	do		
Everett	do	do	None	Do.
Marysville	do	do	do	Lake Stephens.
Monroe	do	do	do	Skykomish River.
Monte Cristo	do	do	do	None.
Silverton	do	do	do	
Snohomish	do	do	do	Do.
Spokane County:				
Cheney	do	do		
Hillyard	do	do		Do.
Latah	do	do	None	Springs.
Medical Lake	Hard	do	do	None.
Stevens County:				
Bossburg	Soft	do	do	Do.
Colville	do	do	do	Do.
Marcus	do	do	do	Do.
Northport	Hard	do	do	Do.
Springdale	Slightly alkaline	do	Surface drainage.	Do.
Thurston County:				
Olympia	Soft	do	None	Do.
Tenino	do	do	do	Do.
Wallawalla County:				
Waitsburg	do	do		Deep wells.
Walla Walla			None	
Whatcom County:				
Blaine		Good		
Fairhaven	Soft	do	None	None.
Sumas	do	do	Surface drainage	Deep well.
Whatcom	do	do	Lumber mills	None.
Whitman County:				
Colfax	do	do		Deep wells.
Oakesdale	do	do	None	None.
Pullman	Hard	do	do	Do.
Tekoa	Soft	do	do	Do.
Uniontown	do	do	do	Do.
Yakima County:				
North Yakima		do	do	Do.
Prosser	Soft	do	do	

Municipal water supplies in Washington—Continued.

Location.	System of waterworks used.	Depth of the wells.	Depth at which water is commonly found.	Character of the water-bearing material.	Depth of water from surface.
Adams County:		*Feet.*	*Feet.*		*Feet.*
Ritzville	Pumping and gravity.	*a* 385 *b* 200	*c* 50	Porous	20
Asotin County:					
Asotin		20–35	25	Gravel and sand	10
Clarkston	Gravity				
Chehalis County:					
Aberdeen	Direct pressure	20–40		Sand	
Cosmopolis	Gravity	10	10	do	(*d*)
Hoquiam	Pumping and gravity.				
Montesano	Gravity	35	30	Cement and gravel.	25–30
Ocosta		50	40–50	Sand	
Chelan County:					
Chelan	Gravity	Deep.	40–100		(*e*)
Lakeside		20–40	Level of lake.	Sand	(*f*)
Wenatchee	Gravity				
Clallam County:					
Port Angeles	do	12–40	10–20	Sand and gravel	10
Port Crescent		16–20	10–12	Sandstone	6
Clarke County:					
Vancouver	Gravity	30–75	25	Gravel	25
Columbia County:					
Dayton	do		25–50	Basalt	
Cowlitz County:					
Castlerock	do		15	Gravel	12
Kalama	do		10	Basalt	10
Douglas County:					
Wilsoncreek		12–54	48	Gravel	
Jefferson County:					
Port Ludlow	Gravity				
Port Townsend	Direct pressure	22–100		Sand and gravel	
King County:					
Auburn		40–50	40	do	
Ballard	Direct pressure	20–160	12–150	do	
Columbia City	Gravity	12–50	10–30	do	
Enumclaw	do		10–30	do	
Issaquah	do	20–30	20	Gravel	2–18
Kent	do		(*d*)	Sand and gravel	
Renton	do	10–45	10–25	Gravel	6–8
Seattle	do	15–50	12–40	Sand and gravel	10–35
West Seattle	Direct pressure	30–75	50	do	25–70
Kitsap County:					
Bremerton	Gravity		10	Sand	
Charleston	do	20–150	20–150		
Port Blakeley	do		70	Gravel	50
Port Gamble	do				
Kittitas County:					
Clealum	do	10–16	8–12	Sand and gravel	2–8
Ellensburg	do	10–20	10–20	Gravel	(*d*)
Roslyn	Direct pressure	20–60	12–50	Sandstone	3
Klickitat County:					
Goldendale	Gravity	12–75	20	Gravel	

a City well.
b Average well.
c Varies on lower ground.
d Nearly to surface.
e No appreciable rise.
f Lake level.

Municipal water supplies in Washington—Continued.

Location.	System of waterworks used.	Depth of the wells.	Depth at which water is commonly found.	Character of the water-bearing material.	Depth of water from surface.
		Feet.	*Feet.*		*Feet.*
Lewis County:					
Centralia	Direct pressure	20–30	18	Gravel	6
Pe Ell			8	do	
Lincoln County:					
Davenport	Gravity	20–60	20–40	Basalt	10
Harrington	do	30–100	35	do	20
Sprague	do	20–40	20	Gravel and sand	4–20
Wilbur	do		10–15	Basalt	6–8
Mason County:					
Shelton	do	10–50	10	Gravel	
Okanogan County:					
Loomis	do	20–30	20		
Pacific County:					
Ilwaco	do				
Southbend	do	10–60			
Pierce County:					
Buckley	Direct pressure	20–60	30	Sand	10
Carbonado	Gravity				
Orting	do	6–20	10	Gravel	
Puyallup	Direct pressure	10–20	6–10	Sand	
South Tacoma	do	40–50	40	do	40
Sumner	Gravity				
Tacoma	do	30–100	50	Gravel	30–100
San Juan County:					
Friday Harbor		13–18	10	do	6–8
Skagit County:					
Anacortes	Gravity	10–80	16	do	
Hamilton		10–25	18	Sand and gravel	
Laconner	Gravity			Sand	
Mount Vernon	do	12–14			
Snohomish County:					
Arlington		20–30		Sand and gravel	
Edmonds	Gravity			do	
Everett	do	15–115	100	do	
Marysville			14	Sand	8
Monroe	Gravity	18–50	25	Gravel	8–40
Monte Cristo	do				
Silverton	do				
Snohomish	do		15–55	Gravel	10–45
Spokane County:					
Cheney	Direct pressure	30–50	40	Basalt	
Hillyard	do	190–200	190	Gravel	185
Latah		25–40	35	Rock	
Medical Lake		10–40	15	Basalt	
Stevens County:					
Bossburg	Gravity				
Colville	do	10–30	20	Sand	5–8
Marcus			18–60	Gravel	
Northport	Gravity				
Springdale	do	30–100	40–50	Sand	15–75
Thurston County:					
Olympia	do				
Tenino		25–40	35	Gravel	

Municipal water supplies in Washington—Continued.

Location.	System of water works used.	Depth of the wells.	Depth at which water is commonly found.	Character of the water-bearing material.	Depth of water from surface
		Feet.	*Feet.*		*Feet.*
Wallawalla County:					
Waitsburg	Gravity	40–60	16–40		12–16
Walla Walla	do	10–20		Gravel	
Whatcom County:					
Blaine	do	10–20	10	do	
Fairhaven	do				
Sumas		40–90	40–60	Sand and gravel	
Whatcom	Gravity				
Whitman County:					
Colfax	do	12–120	40	Basalt	
Oakesdale		12–60	10–45	Sand and gravel	10–30
Pullman	Gravity	100–130	100	do	(a)
Tekoa		100–176	100	Basalt	b 10
Uniontown		175–200		do	
Yakima County:					
North Yakima	Gravity	18–25		Gravel	
Prosser	do	30–40	35	do	35

Location.	Amount of water obtained daily.	Increase or decrease in supply.	Variation in water level.	Effect of pumping on water level.	Other uses besides domestic supply.
Adams County:	*Gallons.*				
Ritzville		Stationary	No	No	Lawns and gardens.
Asotin County:					
Asotin		do	No	Little	Do.
Clarkston					Irrigation.
Chehalis County:					
Aberdeen					
Cosmopolis		Stationary	No	No	Boiler supply.
Hoquiam					Manufacturing.
Montesano		Stationary	Yes	Yes	
Ocosta		do	Yes		
Chelan County:					
Chelan		do	Yes	Yes	Irrigation.
Lakeside		do	Yes	No	Do.
Wenatchee					Lawns and boilers.
Clallam County:					
Port Angeles		Stationary	Yes	Yes	Fire protection and power.
Port Crescent		do	Yes	No	
Clarke County:					
Vancouver		do	Little.	Little	Fire protection, power, etc.
Columbia County:					
Dayton		do	Yes	No	None.
Cowlitz County:					
Castlerock			Yes	Yes	Power.
Kalama		Stationary	Yes	Yes	Irrigation.

a A few feet above. b Above.

Municipal water supplies in Washington—Continued.

Location.	Amount of water obtained daily.	Increase or decrease in supply.	Variation in water level.	Effect of pumping on water level.	Other uses besides domestic supply.
Douglas County:	*Gallons.*				
Wilsoncreek			No	No	None.
Jefferson County:					
Port Ludlow					Boiler supply.
Port Townsend	250,000	Stationary	Yes	Yes	None.
King County:					
Auburn					None.
Ballard	300,000	Stationary	No	No	Fire protection.
Columbia City			Yes	No	Irrigation.
Enumclaw		Stationary	Yes	Little	None.
Issaquah		do	Yes	No	Do.
Kent					Boiler supply.
Renton	120,000	Stationary	No	No	Fire protection and boiler supply.
Seattle	22,500,000	do	Yes		Fire, irrigation, etc.
West Seattle			No	No	None.
Kitsap County:					
Bremerton			Yes	Yes	Fire protection and boiler supply.
Charleston		Decreasing	Yes	No	None.
Port Blakeley					Do.
Port Gamble	150,000	Stationary	No	No	Fire protection and boiler supply.
Kittitas County:					
Clealum		do	Yes	No	Irrigation, fire protection and boiler supply.
Ellensburg		do	Yes		Irrigation and boiler supply.
Roslyn		Decreasing	Yes	Yes	Fire protection and boiler purposes.
Klickitat County:					
Goldendale		Stationary	No	No	Irrigation and fire protection.
Lewis County:					
Centralia			Yes	No	None.
Pe Ell		Stationary	Yes	No	Do.
Lincoln County:					
Davenport		do	No	No	Irrigation and fire protection.
Harrington			No	No	Do.
Sprague		Stationary	Yes	No	Do.
Wilbur		do	No	No	Irrigation.
Mason County:					
Shelton		do	Yes		Fire protection.
Okanogan County:					
Loomis					Boiler supply.
Pacific County:					
Ilwaco					None.
Southbend					Boiler supply.
Pierce County:					
Buckley	1,200,000	Stationary	No	No	Fire protection.
Carbonado	20,000				Boiler supply.
Orting			Yes	Very little.	None.
Puyallup			Yes	No	Do.
South Tacoma	150,000	Increasing	Yes	Yes	Boiler supply.
Sumner					
Tacoma	8,000,000	Stationary	Yes	No	Boiler supply, fire protection, etc.

Municipal water supplies in Washington—Continued.

Location.	Amount of water obtained daily.	Increase or decrease in supply.	Variation in water level.	Effect of pumping on water level.	Other uses besides domestic supply.
San Juan County:	*Gallons.*				
Friday Harbor			Yes		Boiler supply.
Skagit County:					
Anacortes		Stationary	Yes	No	Do.
Hamilton		do	Yes	No	None.
Laconner					Do.
Mount Vernon		Increasing	No	No	Fire protection.
Snohomish County:					
Arlington			No	No	None.
Edmonds					
Everett			Yes	Yes	Fire protection, boiler supply, etc.
Marysville			Yes	No	None.
Monroe			Yes	Yes	Do.
Monte Cristo					Boiler supply and concentrator.
Silverton					Concentrator.
Snohomish			No		Boiler supply.
Spokane County:					
Cheney			No	No	Fire protection.
Hillyard		Stationary	Yes	Yes	Irrigation.
Latah					
Medical Lake					
Stevens County:					
Bossburg					
Colville		Stationary	No	No	None.
Marcus					
Northport					
Springdale			No	No	Boiler supply.
Thurston County:					
Olympia	3,000,000				Fire protection, boiler supply, etc.
Tenino		Stationary	Yes	Yes	None.
Wallawalla County:					
Waitsburg					Water motor.
Walla Walla			Yes		Fire protection.
Whatcom County:					
Blaine		Increasing	Yes		Boiler supply.
Fairhaven					Boiler supply and fire protection.
Sumas		Stationary	No	No	None.
Whatcom					Boiler supply and fire protection.
Whitman County:					
Colfax					Do.
Oakesdale		Stationary			Fire protection.
Pullman	300,000	Decreasing	No	Yes	Boiler supply and fire protection.
Tekoa		Stationary	No	No	None.
Uniontown		do	No	No	Street sprinkling.
Yakima County:					
North Yakima					Irrigation.
Prosser			No	No	Do.

Representative springs in Washington.

County and post-office.	T.	R.	S.	Owner of spring.	Topographic position.	Quantity of flow.
						Gallons.
Adams County:						
Washtucna	15	36	28 33	G. W. Bassett	Base of bluff	a 40
Chelan County:						
Wenatchee	22	19	24	George Brisson	do	a 8
Clark County:						
Vancouver	1	2	3, 4	Vancouver Waterworks Co.	Hillside	b 1,750,000
Columbia County:						
Dayton	9	39	3	City of Dayton	do	
King County:						
Berlin		11		Everett Bottling Works.	do	a 3
Issaquah	24	6	27	Gilman Water Co.	Head of canyon	
Kent	22	5	19	Town of Kent	Base of steep hill.	b 500,000
McCain	13	26	29	T. G. McCain	Foot of mountain.	a 3
Renton	28	5	20	Seattle Electric Co.	Hillside	b 183,013
Klickitat County:						
Glenwood	9	12		United States	Valley	
Do	6	13		do	Base of bluff	
Goldendale	4	14			In canyon	
Lincoln County:						
Davenport	25	37	21	Town of Davenport.	Base of bluff	b 360,000
Harrington	23	36	34	J. L. Ball		a 2
Do	23	36	14	J. E. Ludy	Deep valley	
Do	23	36	9	L. T. Luper	Valley	b 28,800
Sherman	29	33	25	H. B. Fletcher	do	
Mason County:						
Shelton	20	4	12	Town of Shelton	Hillside	
Pierce County:						
Carbonado	18	6	4	Carbon Hill Coal Co.	do	
Orting	19	5	29	Orting Light and Water Co.	do	
Puyallup	20	4	32	City of Tacoma	Base of bluff	b 18,000,000
Skamania County:						
Cascades	2	7	16	Thomas Moffatt	Hillside	b 25,000
Spokane County:						
Latah	21	45	26	William Forthman.	Base of bluff	b 720
Stevens County:						
Colville				J. U. Hofeteta	Valley	
Wallawalla County:						
Walla Walla				City of Walla Walla.	do	
Yakima County:						
Fort Simcoe	11	15	9	Yakima Indians	Narrow valley	b 57,600

a Miner's inches b Daily.

Representative springs in Washington—Continued.

County and post-office.	Variation in flow.	Taste.	Temperature.	Quality of water.	Kind of rock.
			°F.		
Adams County:					
Washtucna	None	Pleasant	40	Soft	Basalt.
Chelan County:					
Wenatchee	Decreases in flow in autumn.	do	55	Hard	Do.
Clarke County:					
Vancouver	Varies slightly	do		Soft	
Columbia County:					
Dayton	Decreases in summer	do		do	
King County:					
Berlin	None	Soda		Alkaline	Syenite.
Issaquah	do	Pleasant		Soft	
Kent	Decreases in summer	do		do	
McCain	None	Sulphur	122	Sulphur	Granite.
Renton	Diminishes in autumn	Pleasant		Soft	
Klickitat County:					
Glenwood	None	do			Basalt.
Do	do	Unpleasant	76	Charged with gas.	Do.
Goldendale	do	Mineral	100	do	Do.
Lincoln County:					
Davenport	Decreases in summer	Pleasant		Soft	Granite.
Harrington	None			do	
Do	Decreases in summer	Pleasant	45	do	Basalt.
Do	None	do		do	
Sherman	do	do		do	
Mason County:					
Shelton	do	do		do	
Pierce County:					
Carbonado	Decreases in summer	do	54	do	
Orting	None	do		do	
Puyallup	do	do		do	
Skamania County:					
Cascades	do	Sulphur	96	Sulphur, iron, etc.	
Spokane County:					
Latah	Maximum in spring	Pleasant		Soft	
Stevens County:					
Colville	None	do		do	
Wallawalla County:					
Walla Walla	do	do		do	
Yakima County:					
Fort Simcoe	do	Soda	Warm	Charged with gas.	

Representative springs in Washington—Continued.

County and post-office.	Seeps or stream.	Deposits of mineral matter about spring.	Use of water.	Improvements at spring.	Improvements contemplated.
Adams County:					
Washtucna	Stream	None	Town supply and irrigation.	None	None.
Chelan County:					
Wenatchee	do	do	Domestic and irrigation.	do	Do.
Clarke County:					
Vancouver	do	do	City water supply	do	Do.
Columbia County:					
Dayton	Seeps out	do	do	do	Do.
King County:					
Berlin	Stream	Iron	None so far	do	Hotel.
Issaquah	do	None	Town supply	do	None.
Kent	do	do	do	do	Storage reservoir.
McCain	Seeps out	do	Medicinal and bathing.	Hotel	Addition to hotel.
Renton	do	do	Town supply	None	None.
Klickitat County:					
Glenwood	Stream	Iron	None	do	Do.
Do	do	Yes	do	do	Do.
Goldendale	do	Iron	do	do	Hotel and a bath house.
Lincoln County:					
Davenport	do	None	City supply	do	None.
Harrington		do	Domestic		
Do	Stream	do	do	None	Do.
Do	do	do	do	do	Do.
Sherman	do	do	do	do	Do.
Mason County:					
Shelton	do	do	Town supply	do	Do.
Pierce County:					
Carbonado	do	do	do	do	Do.
Orting	do	do	Domestic	do	Do.
Puyallup	do	do	City supply	do	Do.
Skamania County:					
Cascades	Seeps out	do	Medicinal, domestic	Hotel and bath house.	New hotel and bath house.
Spokane County:					
Latah	Stream		Domestic	None	None.
Stevens County:					
Colville	Seeps out	do	Town supply	do	Do.
Wallawalla County:					
Walla Walla	Stream	do	City supply	do	Do.
Yakima County:					
Fort Simcoe	Seeps out	Iron	Bathing	do	Do.

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O

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Author.

Landes, Henry, 1867—

. . . Preliminary report on the underground waters of Washington, by Henry Landes. Washington, Gov't print. off., 1905.

85 p., 1 l. pl. (chart) 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 111.)

Subject series: O, Underground Waters, 29.

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Series.

U. S. Geological survey.

Water-supply and irrigation papers.

no. 111. Landes, H. Preliminary report on the underground waters of Washington. 1905.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

SERIES K—PUMPING WATER.

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PP 32. Geology and underground water resources of the central Great Plains, by N. H. Darton.
WS 111. Preliminary report on the underground waters of Washington, by Henry Landes. 1905.

The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, Bulletin No. 138.

SERIES P—HYDROGRAPHIC PROGRESS REPORTS.

Progress reports may be found in the following publications: For 1888–89, Tenth Annual, Pt. II; for 1889–90, Eleventh Annual, Pt. II; for 1890–91, Twelfth Annual, Pt. II; for 1891–92, Thirteenth Annual, Pt. III; for 1893–94, B. 131; for 1895, B. 140; for 1896, Eighteenth Annual, Pt. IV, WS 11; for 1897, Nineteenth Annual, Pt. IV, WS 15, 16; for 1898, Twentieth Annual, Pt. IV, WS 27, 28; for 1899, Twenty-first Annual, Pt. IV, WS 35–39; for 1900, Twenty-second Annual, Pt. IV, WS 47–52; for 1901, WS 65, 66, 75; for 1902, WS 82–85; for 1903, WS 97–100.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.